Development of an Inexpensive, Automated, Spread-Guiding, System for Air-Floatation Spreading-Tables

For:

Clemson Apparel Research and The Defense Logistics Agency

Contract Number: DLA 900-87-0017 Order Number: 0012

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This report discusses the "Development of an Inexpensive, Automated, Spread-Guiding, System for Air-Floatation Spreading-Tables". The report provides basic background information necessary to understand the nature of the production problems associated with moving spreads. The report uses Quality Function Deployment techniques to analyze cutting room needs and to determine how well commercially available technology addresses those needs. The report then constructs a House of Quality chart to distill basic technical information from the customers' requirements. The report describes how the HOQ information was used to develop and evaluate several prototype guide designs. The report provides a detailed cost evaluation used to justify the final guide design selection. The report discusses the design, installation, testing, and demonstration of the automatic air-floatation guide. And finally, the report provides recommendations for future development of the automatic air-floatation guide.

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ABSTRACT

Large textile and apparel manufacturers spend a great deal of money on automated equipment to convert rolls of fabric into precision cut parts. The rolls of fabric are placed on precision buggies which automatically run up and down long tables unrolling the fabric in layer upon layer. The tables act like huge air hockey tables and make moving the layers of fabric easy. Once the fabric is unrolled, the fabric layers are moved to precision automated cutting equipment which cuts through all the layers producing multiple parts in a single cutting pass. When linked together, all of these precision machines are designed to minimize the time spent converting roll goods into cut parts while maximizing cut part quality. And yet, the quantity and quality of cut parts is limited by the weakest link in the production chain.

If the wrinkle-free layers of fabric are damaged when they are moved from the spreading operation to the cutting operation, all of the money and time spent to produce quality cut parts is wasted. The automatic spreading equipment's output is damaged, and the automatic cutting machine produces miscut parts. Surprisingly, with all the automated equipment commercially available, no equipment exists to automatically move finished spreads of material quickly and damage free.

This report discusses the "Development of an Inexpensive, Automated, Spread-Guiding, System for Air-Floatation Spreading-Tables". The report provides basic background information necessary to understand the nature of the production problems associated with moving spreads. The report

uses Quality Function Deployment (QFD) techniques to analyze cutting room needs and to determine how well commercially available technology addresses those needs. The report then constructs a House of Quality (HOQ) chart to distill basic technical information from the customers' requirements. The report describes how the HOQ information was used to develop and evaluate several prototype guide designs. The report provides a detailed cost evaluation used to justify the final guide design selection. The report discusses the design, installation, testing, and demonstration of the automatic air-floatation guide. And finally, the report provides recommendations for future development of the automatic air-floatation guide.

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Background

Air floatation (also spelled flotation) spreading tables are common in both the Apparel and Textile Industries. These tables are used to transfer or "float" spreads of material, weighing up to several tons, from one section of a spreading table to another section, from one spreading table to another spreading table, or from a spreading operation to another operation. By producing a cushion of air between the table surface and a spread, air floatation tables lower spread-to-table friction forces. By lowering friction, the force necessary to move large spreads is reduced to the pulling force a single man can exert.

Problem

Despite the low pulling forces, a minimum of two people are needed to float a spread. This is because uneven air floatation surfaces and other mechanical properties of the table, spread, and pulling operation, cause the spread to skew while moving. To prevent spread skewing during floatation, additional workers are needed to guide the spread along. Larger spreads require more workers. Unfortunately, the more spreads are manual handled, the more likely they are to be damaged.

Spread damage occurs when spread plies (fabric layers) shift with respect to each other, and, due to frictional forces, are unable to return to their original flat position. Whenever spreads are bent, twisted, pushed, pulled, or pinched, ply shifting occurs. Ply shifting causes wrinkles, and within the spread, these wrinkles are impossible to remove. Consequently, when a

wrinkled spread is cut, the cut-piece contours are stepped where the wrinkles were cut across. The resulting miscut pieces are difficult to sew and are often the source of second-quality sewn products. Even if automated cutters are used, damaged spreads will produce miscut parts.

When cutting large spreads computer numeric controlled cutters (CNC cutters) must cut a section of the spread and then pull in the next spread section while simultaneously off-loading the cut pieces for assembly. This process is called cutting "bites". CNC cutters cut bites of fabric based on the assumption that the fabric is where it is supposed to be. If a spread is not aligned with the cutter, the cutter has no way of knowing. Spread skewing causes the fabric to move with each bite the cutter takes. Since the cutter has no way of knowing the spread has shifted, the cutter cuts pieces even if there is no fabric present under the cutting head. Miscuts caused by spread skewing are characterized by flat sides where the cutter cut beyond the edge of the fabric in the spread.

Need

To avoid problems resulting from distorted and skewed spreads, many cutting operations have recognized the need for guides to assist in moving and aligning their spreads. But, because few of the companies that sell spreading and cutting equipment offer spread guides, most guides found in industry are home-made. These guides are designed for specific in-house equipment and processes, and are the result of trade-offs between costs, time savings, and production volumes. As a result, a guide that works for one manufacturer may not be suitable for another. What the industry

needed was a low cost, universal, air floatation, spread guide that minimized spread damage while maximizing production throughput.

Solution

To develop a guide that better meets the needs of the apparel and textile industries, a team of mechanical engineering designers at Clemson Apparel Research (CAR) worked on a project titled The Air Floatation Guide Project (AFGP). After conducting industry surveys of available spread-guide technology, and comparing the cost and performance of the more promising industry guides, the design team abandoned traditional manual guide technologies in favor of a simple, affordable, universally adaptable, and completely automatic guide design. The remainder of this report will justify the development of the automatic guide design, but details (mostly mechanical drawings) of the final guide design cannot be revealed for patent disclosure reasons. Readers should note that at the time this report was written, all of the industry processes, equipment, and opinions listed in this report were current and are therefor discussed in the present tense. Developments made during the course of the AFGP are reported in the conventional manner, in the past tense.

QUALITY FUNCTION DEPLOYMENT DESIGN ANALYSIS

Background

From an engineering perspective, Quality Function Deployment (QFD) is a design tool which helps translate general customer requirements into manufacturable products. From a marketing perspective, QFD establishes a design foundation, based on customer desires, and promotes the systematic development of sellable products. In either case, QFD employs four basic steps in systematically translating customer needs into final products[1]:

- Product Planning
- Product Design
- Process Planning

and

- Process Control Planning

Starting with Product Planning, customer requirements are converted into technical requirements. In the Product Design phase technical requirements are then converted into part characteristics. In the Process Planning phase part characteristics are changed into process characteristics. Finally, in the Process Control Planning phase, process characteristics are converted into process control methods[2].

The entire process of going from customer requirements to finished product is technically complex, and QFD encourages all departments in manufacturing facilities to provide input. By incorporating information

from a broad range of manufacturing expertise, QFD promotes the systematic development of products that customers will buy. Unfortunately, executing all four stages of QFD is not only technically difficult but also time consuming and expensive.

Since CAR is not a machine manufacturing facility, CAR does not have the in-house expertise to carry out a complete QFD analysis. CAR does, however, serve as an interface between apparel/textile customers and apparel/textile machine manufacturers. CAR also has an in-house, full-production, manufacturing facility, and a basic, metal working, machine, shop.

With the above mentioned attributes, the AFGP design team completed the Product Planning phase by

- Identifying customers' spread-moving needs,
- Determining how well existing technology, meets those needs

and then,

- Formulating guidelines for new technologies so that customers' needs would be better met.

The guidelines developed in the Product Planning phase took form as a ranked list of general technical requirements.

In the second phase of a QFD analysis, called the Product Design phase, general technical requirements are used to design specific parts for product improvement. To successfully use QFD Product Design techniques, design teams must have an existing machine concept to improve upon. The AFGP

Product Planning phase produced a list of technical requirement showing that existing guide concepts had to be abandoned. With no guides to serve as a starting point for improvement, there was no way to use the Product Design phase to improve the design of guide parts. Consequently, the QFD Product Design phase was abandoned in favor of less scientific brain-storming, trial and error, and intuitive creative processes. The remaining QFD analysis phases were also not pursued.

As explained earlier, the Process Planning and Process Control Planning phases, of a complete QFD analysis, are used to convert part characteristics into process characteristics and then process characteristics into process control methods. Each phase improves the manufacturability of the product being designed, so that the product can be commercially manufactured for a profit. Since the AFGP objectives did not include commercial product manufacturing, Process Planning and Process Control Planning were not included in the AFGP's QFD analysis. Instead, because the success of QFD analyses begins with Product Planning, the AFGP designers focussed all their attention on developing a thorough Product Plan.

To develop a complete QFD Product Plan, the design team used "House of Quality" (HOQ) charts (see Figure 1, on page 7). HOQ charts are composed of sections which help convert information from customers and competitors into weighted technical requirements. These weighted technical requirements form the basis for new product designs.

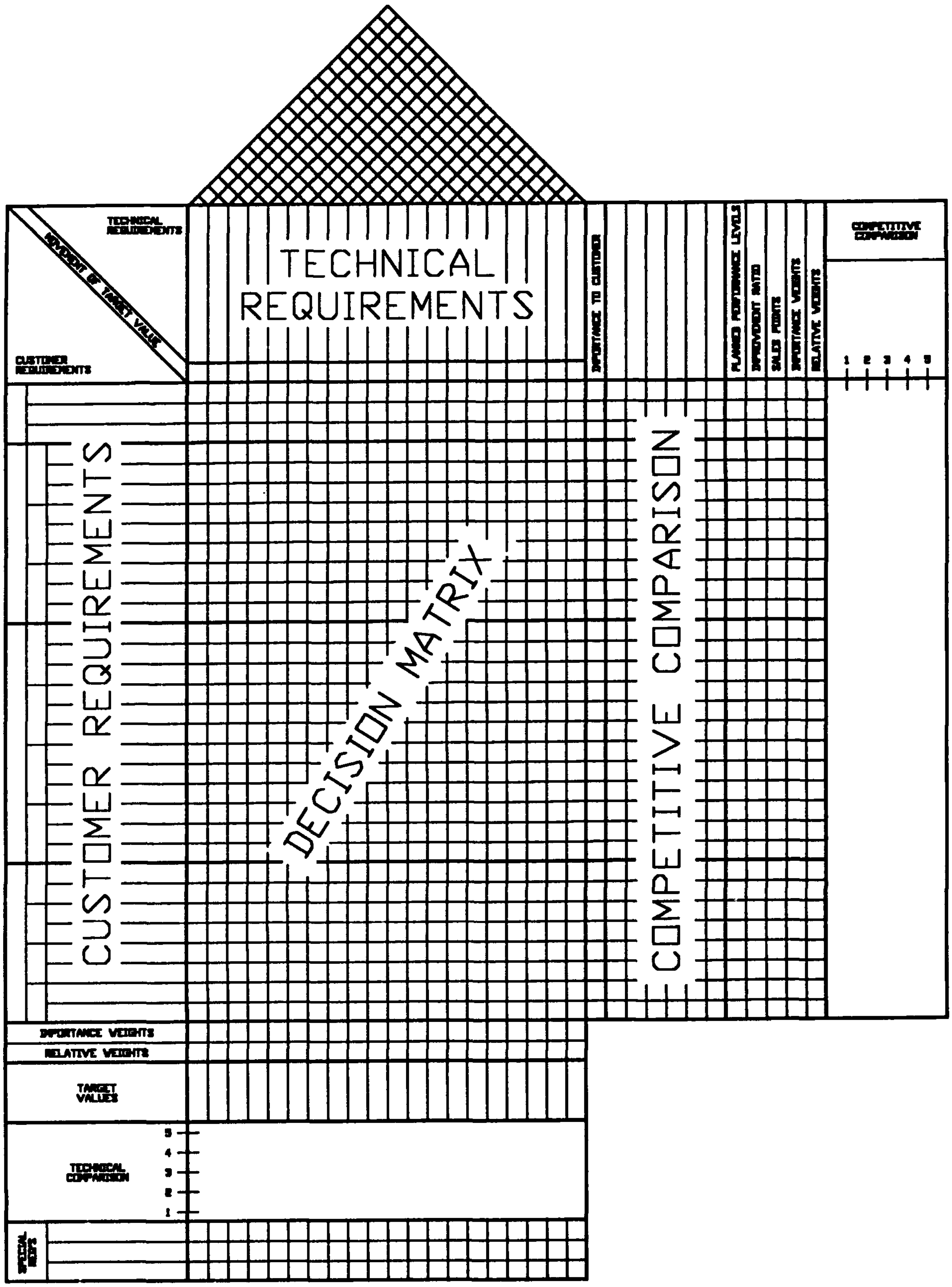


Figure 1 - House of Quality (HOQ) Chart

In this report each step taken in completing the AFGP's HOQ chart is discussed (see Figure 2, on page 9). In filling out the HOQ chart, product ideas were developed, and at the end of the process a final guide design emerged. Interestingly, the difficult process of completing the HOQ chart began with a simple premise: The most important product requirements are those imposed by the prospective customer.

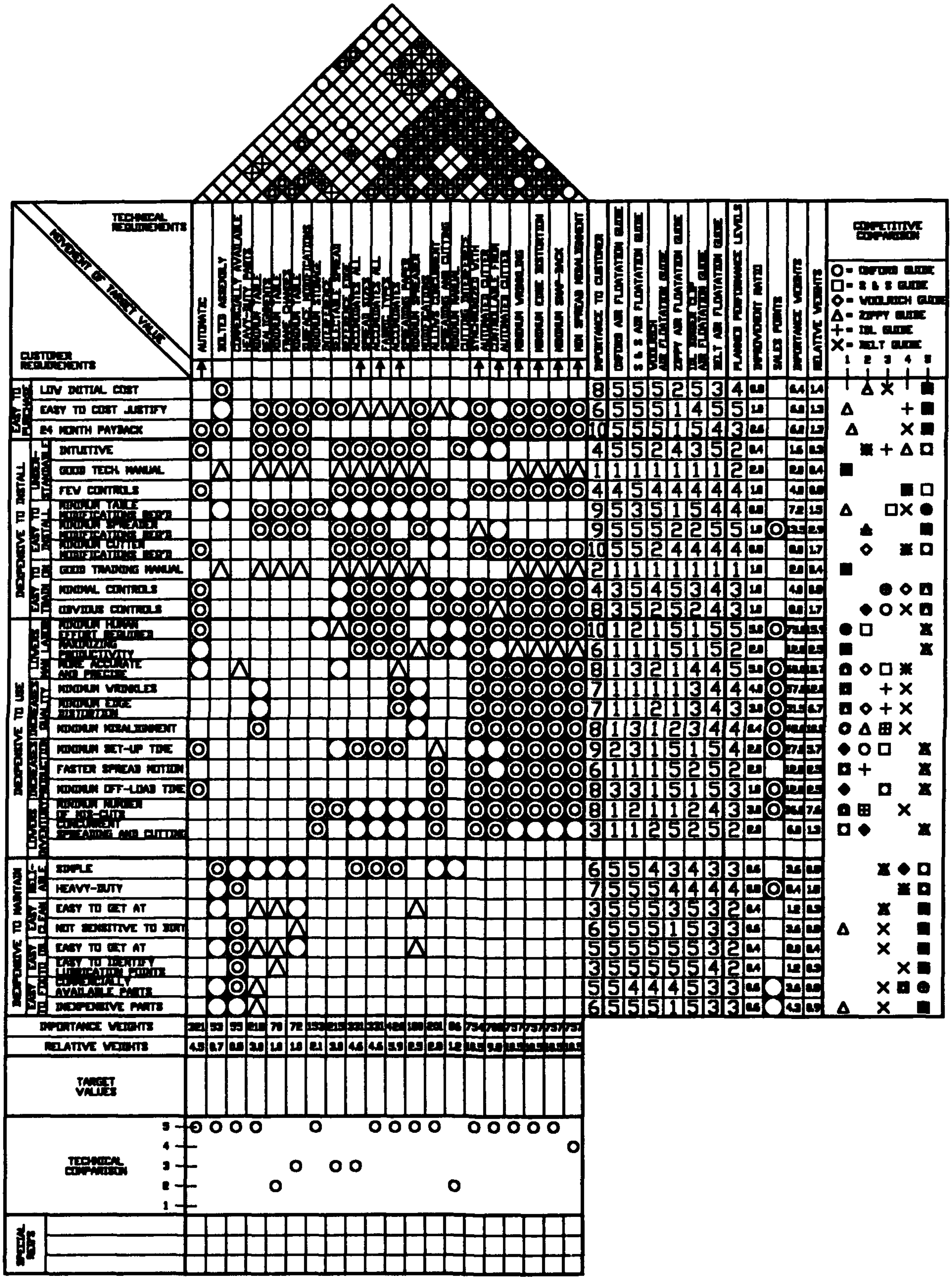


Figure 2 - Air Floatation Guide Project's House of Quality

Customer Requirements

Interviews with cutting room personnel from Carolina Cutters, West Union, SC; Jantzen Inc., Seneca, SC; Oxford Industries, Vidalia, GA; S&S Mfg., Roebuck, SC; and Woolrich Woolen Mills Inc., Woolrich, PA, resulted in the list of desired air floatation guide features given in Appendix A. With the help of the individuals interviewed, and with a basic understanding of apparel industry motives, Appendix A information was reorganized into Appendix B, which was used to complete the "Customer Requirements" section of the HOQ chart.

Appendix B divides customer requirements into the four basic categories:

- Inexpensive to purchase
- Inexpensive to install
- Inexpensive to use

and

- Inexpensive to maintain

These categories should come as no surprise to anyone, and are universally applicable to any machine design. The sub-categories are more interesting, however.

From Appendix B the most notable sub-categories are

- 24 month payback (for equipment purchased)
- Minimum table modifications (for installation)
- Minimum human effort required (for lowering manual labor content of manufacturing)

and

- Minimum set-up time (for increasing production)

Ranking of Customer Requirements

Once a condensed list of customer requirements was established, rankings were assigned to each requirement with ten being most important and one being least important. The ranking information was then placed in the "Importance to Customer" column of the HOQ chart (see Figures 1 and 2, on pages 7 and 9, respectively). While individual rankings can be readily argued, trends in the data support general apparel industry observations.

Based on average ratings for the four main customer requirements (mentioned in the middle of page 10 and given in Appendix B), customers rank purchase expense as the most important factor followed sequentially by operating expense, installation expense, and maintenance expense. The fact that installation expense is of greater concern than maintenance expense stems from the fact that a majority of air floatation guides are so mechanically simple and robust that maintenance is not viewed as a functional concern. Customers also see the prime source of installation expenses as expenses incurred due to equipment modifications. The operating expense heading provides some interesting design insights, which warrant additional discussion.

Four factors help reduced expenses associated with using air floatation guides. When ranked according to customer desires these factors are:

- Decreasing manual labor requirements
- Increasing throughput
- Increasing quality

and

- Decreasing inventory

For air floatation guide customers, as with most apparel customers, decreasing manual labor costs is the main motive for using air floatation guides. Labor costs can be reduced in two ways. Either fewer people are required to perform a given task over a given period of time, or less time is required from the same number of people who originally performed a given task. If a guide reduces the number of people required to move spreads, the guide reduces labor costs. If the guide makes aligning the spread less susceptible to human error, the guide saves time and reduces labor costs. If the guide does anything else to reduced the number of individuals and the amount of time they spend moving spreads (i.e. if the guide maximized their productivity) the left over time and human resources can be redirected to increase production elsewhere. Closely connected to the idea of maximizing productivity is the idea of increasing production throughput.

Increasing production throughput is the next most important customer cost item. Customers see set-up time as the single greatest constraint on guide-related production-throughput. Customers believe that removing guides, to prepare the air floatation table for spreading, is the next greatest throughput constraint. And finally, customers judge the speed at which spreads are actually moved to be the least important throughput constraint. This latter opinion probably stems from the fact that the speed at which spreads can be removed from the air floatation table is a direct function of the speed at which the CNC cutters take bytes out of the spread. As long as a guide is able to feed fabric at the same speed that the cutter processes the fabric, feed rate is not a major concern.

Interestingly, quality benefits also do not rank as a major concern to companies using air floatation guides. Most companies see spread alignment as a labor related issue as opposed to a cut part quality issue. If a guide can prepare a spread for cutting as well as a laborer, the spread preparation is good enough. This observation points out the industry's strong preoccupation with labor related expenses. Edge distortion and ply wrinkling are also viewed as less important factors when considering guide performance.

Decreasing inventory is the least important use issue associated with using air floatation guides. Since the production of spreads is usually more time consuming than cutting of spreads, spreads are continuously in the construction phase. Continuous construction meant that a large amount of fabric inventory are just sitting on the spreading tables waiting for the last ply to be laid so the spread can be completed. Not having to wait for the cutter to finish before making the next spread is a common industry condition because most companies have extra air floatation table space serving as a buffer that allows spreads to be cut while other spreads are being made. The only inventory issue that is a concern is the issue of miscut parts.

If a guide contributes to the miscutting of parts, manufacturers have to prepare replacement parts for those that had been miscut. The need for replacement fabric "just in case" is viewed as undesirable extra inventory. If a spread guide can guarantee that spreads will be transferred to the cutting operation without being damaged or misaligned, customers can

eliminate the guide as a contributing factor in cutting error. Hence, the need for extra inventory will not be associated with the guide.

Survey of Existing Guide Technologies

After determining the basic customer requirements, and ranking those requirements, a performance evaluation of competitive guides took place. Four guides were involved, the Oxford Guide, the S&S Guide, the Woolrich Guide, and the Jantzen Guide. The results of the performance evaluation were put in the HOQ chart columns to the right of the "Importance to Customer" column (see Figures 1 and 2). A visual comparison of the performance data was presented in the "Competitive Comparison" area of the HOQ chart.

In conducting the QFD survey of available air floatation guide technologies the following guide configurations were seen as potentially existing:

- I) Fixed (stationary)
  - A) Recessed (retractable)
    - 1) Position adjustable
    - 2) Non-adjustable
  - B) Non-recessed
    - 1) Position adjustable
    - 2) Non-adjustable
  - C) Partially retractable
    - 1) Position adjustable
    - 2) Non-adjustable

II) Removable

A) Attached to the spread

1) Requiring table modifications

a) Position adjustable

b) Non-adjustable

2) Not requiring table modifications

a) Position adjustable

b) Non-adjustable

B) Attached to the spreading table

1) Requiring table modifications

a) Position adjustable

b) Non-adjustable

2) Not requiring table modifications

a) Position adjustable

b) Non-adjustable

III) Hybrid (i.e.. part of guide is fixed to table, part of guide is removable)

A) Position adjustable

B) Non-adjustable

In the actual survey, the following guides were found (see Table 1, on page 20):

Table 1 - Competitive Guide Designs		
Guide Type	**Manufacturer**	**Description**
Fixed Non-recessed Non-adjustable	Jantzen Inc.	Metal angle bolted to the last half of a spreading table twice as long as the longest spread processed
Removable Attached to table No table mod.'s Adjustable	Oxford Industries	Heavy, metal angle that is manually placed next to the spread before the spread is floated
Removable Attached to table Table mod.'s req'd Non-adjustable	S&S Manufacturing	Custom designed stainless steel guide with rounded edges and positioning posts that is inserted into holes drilled into the spreading table
Removable Attached to spread No table mod.'s Non-adjustable	Woolrich Woolen Mills	Commercially available cloth clamp welded to a sheet metal angle that slides along the edge of the spreading table

Based on the survey, simple metal angles form the basis of a majority of the "made in-house" guide designs. With, for the most part, minor modifications, angles can be formed into any number of guide designs (see Figure 3, on page 21).

Of all the designs encountered, the Woolrich Guide is the most surprising. The Woolrich Guide is the only guide that is not mounted to the spreading table. Instead, one end of the Woolrich Guide clamps to the spread while the other end hangs over the edge of the spreading table. Also, with the Woolrich Guide the spreading table slopes away from the guide. Normally spreading tables slope towards the guides. The difference in table slope

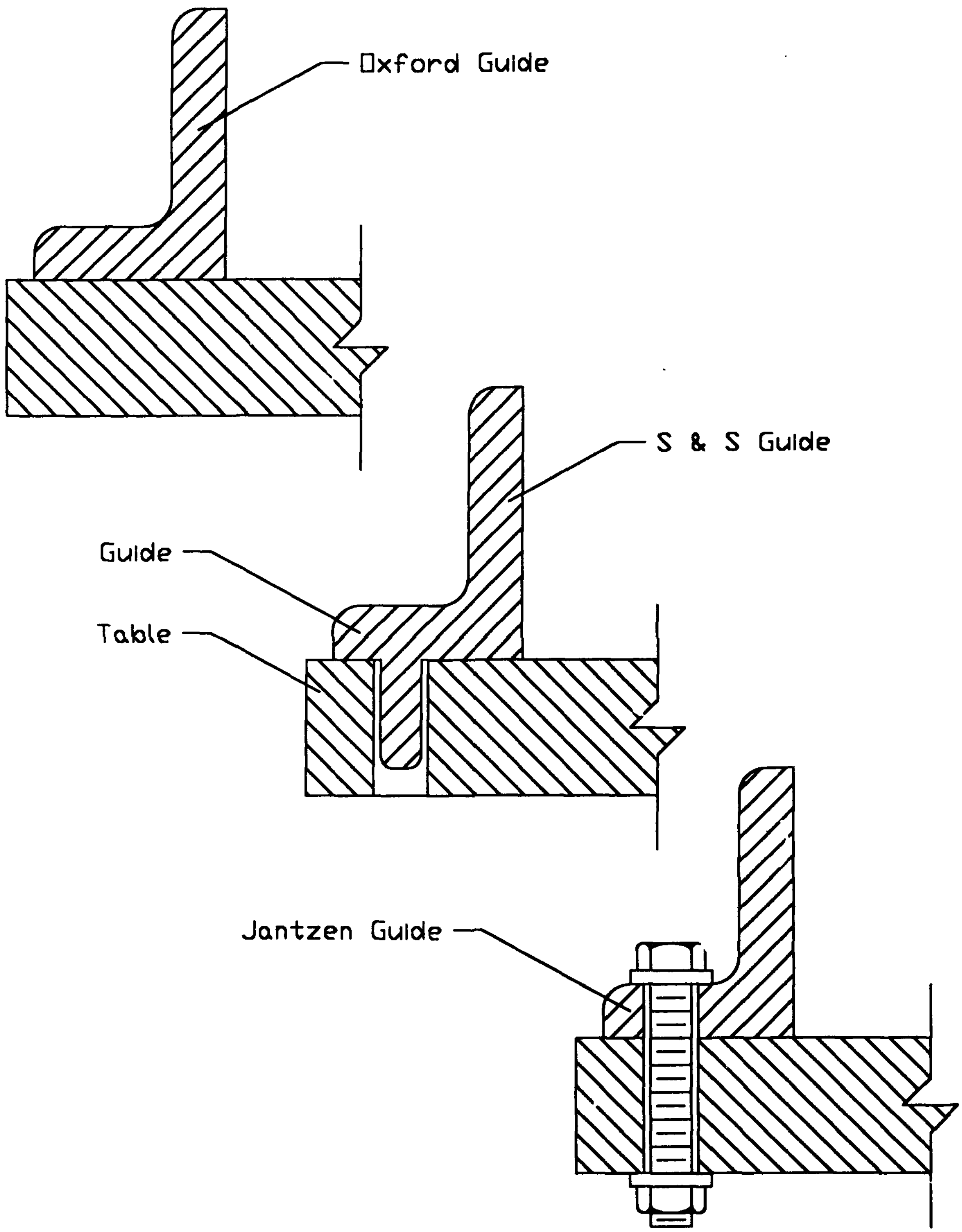


Figure 3 - Guides Made Using Metal Angles

occurs because, instead of pushing the spread away from the low edge of the table, the Woolrich Guide pulls the spread towards the high edge of the table. When the spread moves, the Woolrich Guides slides along the edge of the table, and as the spread is cut, the guides are manually removed. Despite its different approach, the Woolrich Guide performed as well as any of the other guides observed. When compared to the HOQ Customer Requirements list, none of the guides were perfect, however.

Competitive Comparison of Existing Guide Technologies

Based on customer requirements and the associated customer weightings, as shown in the HOQ chart (see Figure 2, page 9), the guides were ranked in Table 2, starting with the most desirable and going to the least desirable.

Table 2 - Customer Guide Rankings

(Based on Customer Requirement Weights)

Manufacturer	Total Score
S&S	110
Jantzen	103[1]
Oxford	101
Woolrich	93

[1] In actuality the Jantzen guide is the least favored because its use requires doubling the spreading table lengths (see explanation below). For these reason the Jantzen guide is not shown in CAR's HOQ chart.

In the air floatation QFD analysis negative numbers were not assigned to guide performance with respect to customer weights. For this reason, the lowest scores that the Jantzen guide could earn, in the customer requirement categories of low initial cost and minimum table modifications, were ones (1's). In actuality the Jantzen guide was the least desirable guide found. The reason the Jantzen guides were poorly received is that the guides are costly to purchase and install because they interfered with spreading operations.

The Jantzen guides are sufficiently tall that spreaders can not be modified to avoid the guides. As a result, any table the guides are bolted to can not be used for spreading. A table that has Jantzen guides and supplies spreads to a CNC cutter has to be twice as long as the spreads it is used to make. The end result is that cutting rooms equipped with Jantzen guides have to

have either a dedicated table with attached guides that move with or to the cutter, or have to have all the tables doubled in length. In both cases substantial structural and procedural modifications have to be made to the cutting room. Such modifications are much more expensive than the guides, and are a direct result of using the guides. Because of the low customer appeal of the Jantzen guide, the Jantzen guide was not included in CAR's HOQ chart.

The Woolrich guide also did not score as high as the other guides. The reason for the Woolrich guide's lower score stems from the fact that it is difficult to set-up and difficult to off-load. Both on- and off-loading required substantial manual labor input. In the off-loading mode, the cutting operator, who is normally bundling cut parts, has to stop bundling, and move to the other end of the cutter to remove the guides before they are pulled onto the cutting bed. Also, despite the guides *excellent* performance while in motion, spreads are wrinkled and misaligned upon entering the cutter. The reason the spreads are damaged is that the guides move the spreads so smoothly!

In getting a spread moving, guides that minimized guide to spread friction work well. Since the Woolrich guides moves with the spread, no frictional forces are exerted between the guides and the spread, and virtually no spread damage occurs. However, once a spread is moving, slowing the spread down is difficult. Because spreads rub against the other guide types, all the other guides exert frictional forces on the spreads. The frictional forces helped slow the spreads down. With the Woolrich Guide there are few if any frictional forces. As a result, if the same end of the spread that

was used to get the spread moving is used to slow the spread down, the spread piles up on itself. In other words, if the spread is moving fast enough, and leading end of the spread is quickly stopped, the spread's inertia keeps the back end of the spread moving, and the spread buckles, causing substantial wrinkling, misalignment, and other associated problems. Unfortunately, since CNC cutters provide the motive forces necessary to move the spreads during cutting, every time the cutters take a bite of the leading edge of the spread, the Woolrich guides caused the spread to buckle. For all of the above reasons, the Woolrich guide did not rank favorably.

The most favorably received guide was the S&S guide. The S&S guide's simplicity, combined with it's reliable positioning, makes the guide a customer favorite. However, the S&S guide is viewed as more complex to make than the Oxford guide, and for this reason, the Oxford guide was chosen as the industry reference. In both cases, the S&S and Oxford guides are inexpensive to buy, inexpensive to install, and inexpensive to maintain. However, all of the guides evaluated can be improved in the area of usage.

None of the guides reviewed meet the customer requirement of minimum human effort. None of the guides decrease the time required to set-up, move, and off-load the spreads with respect to manual guiding. None of the guides avoid using human-beings to actually pull the spreads. And interestingly, none of the guide designs are successful in maintaining spread quality by minimizing wrinkling, edge distortion, and spread misalignment. Looking at costs incurred from ignoring the aforementioned customer requirements, opportunities to satisfy customer

needs with a new air floatation design became apparent. To take advantage of the shortfalls of existing air floatation guide designs, a list of technical requirements was formulated.

Technical Requirements

The technical requirements section of the HOQ chart (Fig. 1, page 7) provided the rough frame-work in which improved guide designs were formulated and evaluated. Using the final customer requirements list from Appendix B, and the information obtained from the evaluation of the competition, preliminary technical requirements evolved (see Appendix C and Appendix D). From Appendix D, a condensed list of technical requirements was derived (see Appendix E). The final list of technical requirements was placed along the top row of the HOQ chart (Fig. 2, page 9).

Most of the technical requirements listed in the HOQ chart stemmed from the customer requirements list. Emphasis was placed on those technical design elements that afforded improvement opportunities. Since the competitive analysis revealed weaknesses in satisfying the customer demand for minimum human effort, a goal was set to pursue a semi- or fully-automatic guide design concept. Since none of the guide designs are successful in keeping spread quality intact, minimizing wrinkling, edge distortion, spread misalignment, and snap-back[3] were technical priorities.

The technical requirements list also attempted to avoid the more obvious guide design pitfalls by minimizing cutting room equipment modifications and avoiding cutting room process modifications. Technical requirements emphasized developing a guide capable of handling all spread sizes, fabric types, and accommodating left or right spread reference edges. Permitting the use of various spreading and splitting papers, common in spreading operations, was also a technical consideration as was minimizing manual cutting interference.

Ranking of Technical Requirements

With a list of general technical requirements in hand, the next step, in developing the HOQ chart, was to establish which technical requirements were to receive a majority of design attention. The basic process is outlined below with references to the appropriate HOQ chart locations given in parentheses (Fig. 1, page 7):

1) Selected a reference product design (Oxford's air floatation guide).
2) Decided which customer requirements the new product design was to focus on (Planned Performance Levels).
3) Compared how well the new product design met customer requirements with how well the reference product design met customer requirements (Improvement Ratio).
4) Determined marketable features of new design (Sales Points)
5) Used all of the above to assign values to the new product's customer-related design-requirements (Importance Weights Column).
6) Normalized the Importance Weights Column (Relative Weights Column).
8) Determined relationships between new product's customer-related design-requirements and the new product's technical design-requirements (Relationship Matrix)

9) Used the Relative Weights Column and the Relationship Matrix to convert weighted customer design requirements into weighted technical design requirements (Importance Weights Row).

10) Normalized the Importance Weights Row (Relative Weights Row).

The entire process of translating customer requirements into weighted technical requirements was tedious and non-intuitive. For the sake of time, the detailed process is not discussed in this report. The inquisitive reader should refer to Robert Keith Daniel's thesis "Enhance the Commercial Acceptance of an Automatic Ply Separation & Feeding System for Apparel Fabrics", Oct. 28, 1991, North Carolina State University, Master of Integrated Manufacturing Systems Engineering under Dr. Timothy G. Clapp, Professor of Textile Engineering and Science.

In translating customer requirements into weighted technical requirements, ten technical requirement stood out in sharp contrast to all the rest. The ten requirements are listed below with their associated relative weights. The higher the relative weights, the more important the technical requirement (see Table 3 on the next page).

Table 3 - Weighted Technical Requirements	
Technical Requirements	Relative Weights
Automatic	4.5
Accommodates all spread sizes	4.6
Accommodates all fabric types	4.6
Accommodates spreading paper	5.9
Controllable from automated cutter	9.8
Synchronized with automated cutter	10.5
Minimum wrinkling	10.5
Minimum edge distortion	10.5
Minimum snap-back	10.5
Minimum spread misalignment	10.5

Table 3 shows that, at the time of analysis, the most important design objective of any new air floatation guide concept was the minimization of spread distortion that would normally result in miscut parts. The next most important design objective was the synchronization of the spread motion with the CNC cutter feed. Accommodating all spread configurations was important if the guide was to perform as well as existing guides. And, if the new guide could be made automatic, labor savings could be realized. With the weighted technical requirements in hand, work began on brainstorming and testing design ideas. Each design idea served as a potential solution to the customer's needs by meeting some, if not all, of the related technical requirements.

POTENTIAL SOLUTIONS

IDL Guide, Initial Investigation

The first design concept considered was an off-shoot of the Woolrich Guide and was called the IDL Guide. The idea was to produce a guide that avoided spread edge distortion, caused by spread to guide friction and edge clamping, and that minimized spread misalignment. The guide would also accommodate all spread types and all cutting room processes and equipment. To minimize the amount of manual labor required to set up the guide, the guide would be permanently attached to the air floatation table. To keep costs down the guide would be simple and easy to install. The resulting design concept is shown in Figure 4, on page 32.

Figure 4 shows a small, tensioned, metal cable running the length of the air floatation table. Hooked to the cable are small but strong clamps. Because of their low profile, low cost, and availability, IDL Binder Clamps (office paper clamps) were used. The back of the IDL Binder Clamps were loosely fastened around the cable allowing the clamps to slide freely up and down the cable. The clamping end of the IDL Binder Clamps fastened to the spread. Since the whole spread rests on the lowest plies of the spread, clamping just the first few bottom plies of the spread allowed the whole spread to be controlled. When tested, the clamp worked fairly well.

The IDL Guide's biggest drawbacks were that it did not avoid the problem of spread buckling experienced with the Woolrich Guide, and that it was not automatic. To solve the problem of spread buckling, a tensioning device was considered. A large tape measure with a clamp on the front end of the tape,

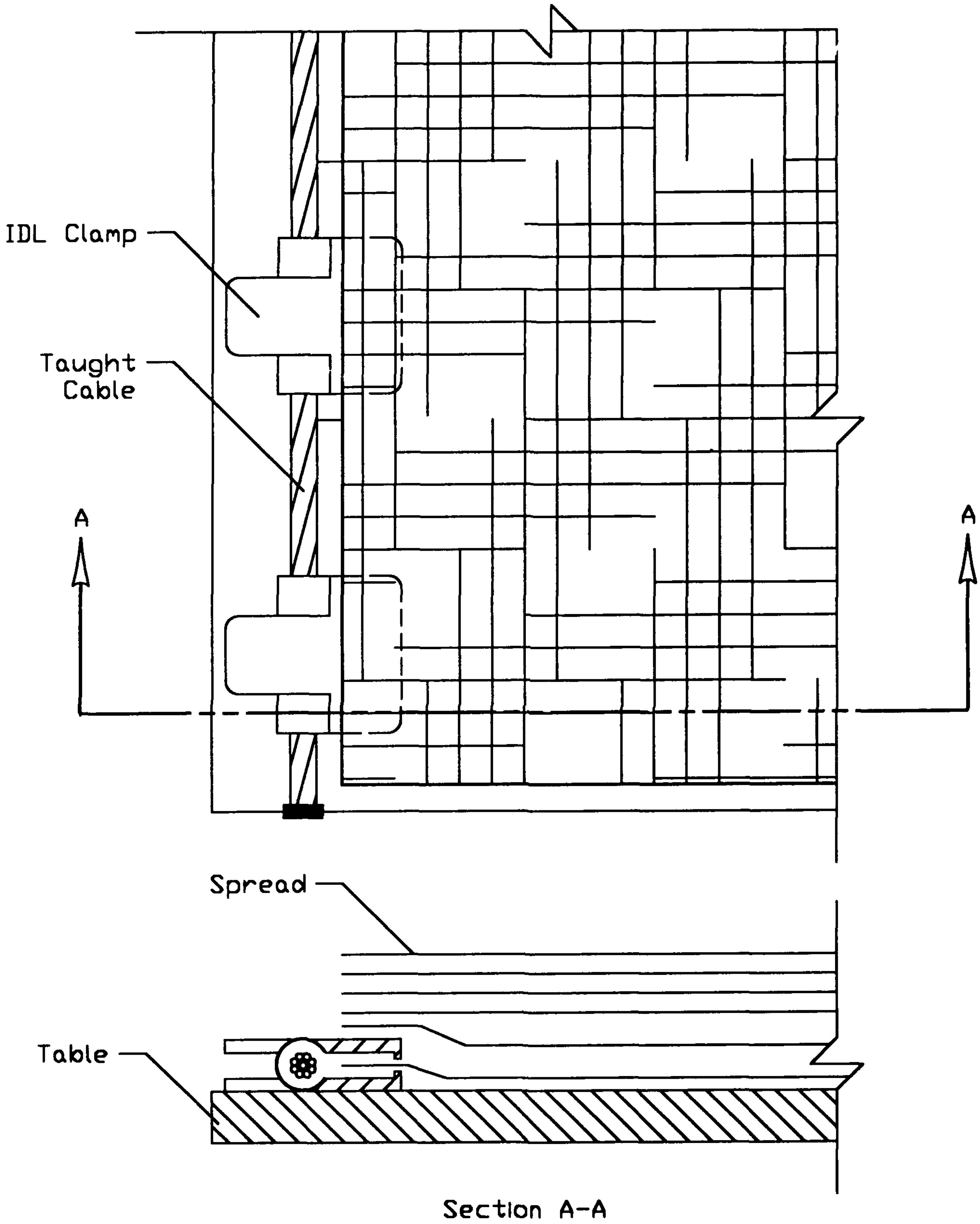


Figure 4 - IDL Guide

was fastened to the end of the spread farthest from the cutter. When the spread was pulled from the front, the tape kept the spread under tension. The tension prevented the spread from buckling when the spread was slowed down. A simpler and more cost effective way of attaining the same effect was to prevent the end-most clamp from sliding freely. With a simple solution to the spread buckling problem in hand, the next step was to make the guides more automatic.

To make the IDL Guides less dependent on human intervention, automatic clamping and unclamping concepts were brainstormed. After performing some basic positioning and force calculations even the simplest automatic clamp concepts were deemed too complex and unreliable to be worth further consideration. Moving the spreads automatically, on the other hand, seemed a more attainable objective.

Three basic ideas were tested. The first idea used a tensioning device, clamped to the front of the spread, to pull the spread to the cutter. The second idea involved using the automated spreading buggy to pull the spread into place, and the third idea involved modifying the air floatation air jets. After consideration, only the last idea reduced the amount of human effort required to move the spread, the other ideas simply changed the way human effort was applied without actually eliminating the human effort.

Zippy Guide, Initial Investigation

The idea of using the air floatation air jets to move the spread came from observations of air jet equipment. At the September 1990 Bobbin Show

several air jets were introduced to the apparel industry. These air jets use low volumes of high velocity air to move fabric from one location to the next. By covering the air holes in CAR's air floatation table with small patches of plastic, it was possible to direct the air coming out of the table. In this way air holes of the air floatation table were converted into directed air jets (see Figure 5, page 35).

When single plies of fabric were placed on the modified air floatation table, the plies were whisked down the table at substantial speeds. Unfortunately, redirecting the air coming out of the air floatation table had the same affect as partially blocking the air holes. The partial blockage of the air holes caused back pressure in the table air-supply pipes which caused excess fan heat and reduced air floatation capacity. As a result, the modified air jets were only able to move spreads a few plies high. For larger spreads there was not enough air to sufficiently overcome the table to spread friction forces, and so the larger spreads did not move at all.

As efforts focussed on automatically move the spreads using air jets, the thought of using more powerful air jets arose. As mentioned earlier, at the 1990 Bobbin show a number of air jets were introduced. One of these air jets was used to feed and align two plies of fabric into a surging sewing operation. For the purpose of experimentation, CAR purchased five of the air jets called "Zippy Air Guides". To avoid confusion, the Zippy Air Guides were called Zippies. The air flotation concepts that used Zippies were called Zippy Guides.

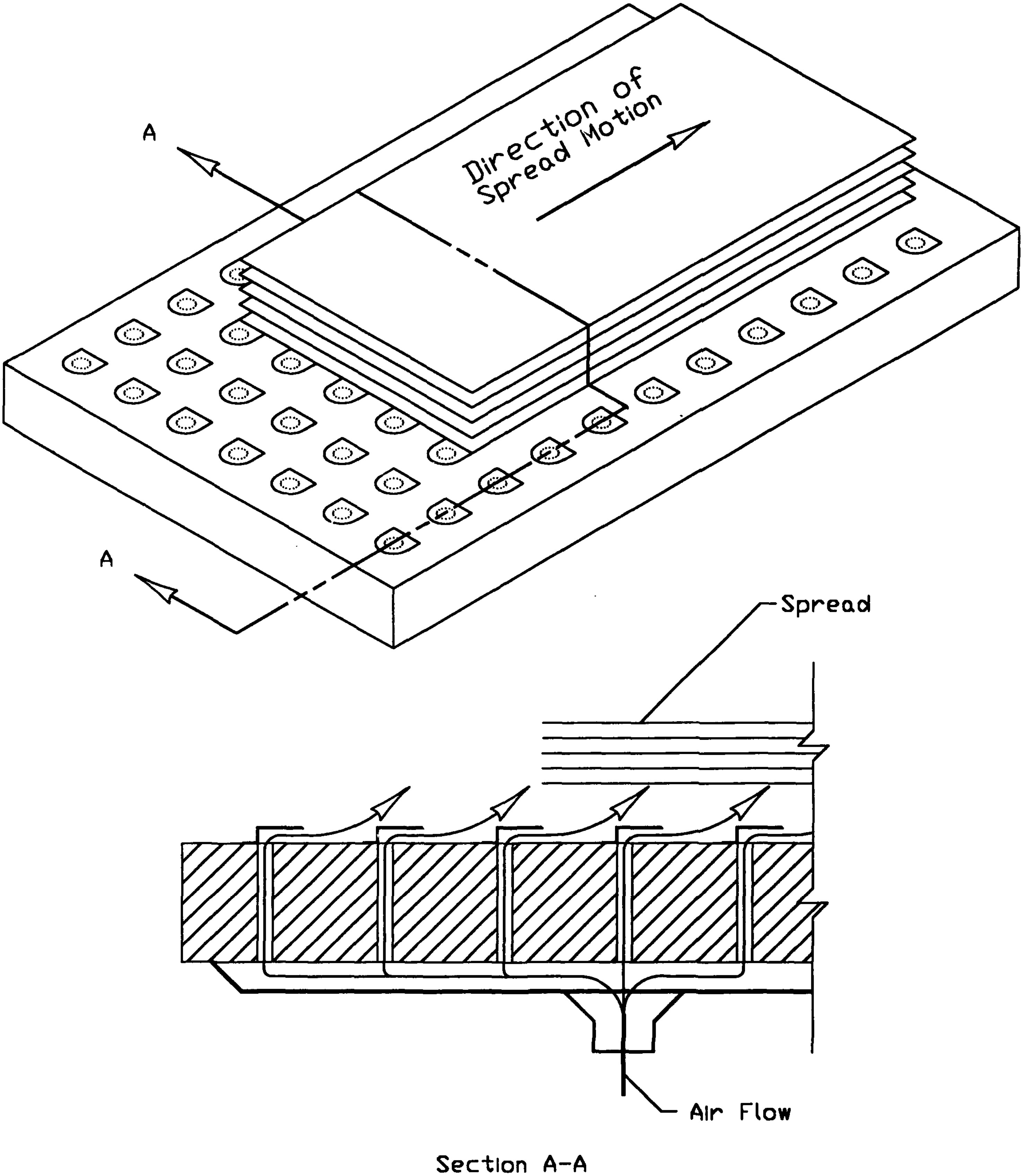


Figure 5 - Conversion of Air-Floatation Holes into Directed Air-Jets

In testing the Zippies, several drawbacks became apparent. First, although the Zippies were able to move single plies of fabric well, larger spreads required more Zippies. Second, the more Zippies that were added, the harder it was to adjust the Zippies to ensure that the spread was sent in the correct direction when the Zippies were turned on. To counteract the problems associated with directing spreads using Zippies, several trough guide-configurations were tested.

The first trough configuration tested involved raising the edges of the spreading table (see Figure 6, page 37). Unfortunately, when the trough depth was sufficient to overcome the spread shifting tendencies, resulting from uneven table characteristic, spreading cloth wrinkle-free became impossible. This is because the cloth, coming off the spreader straight, was forced to bend in compliance with the spreading table surface. To avoid the spreading-related problem of wrinkling, a different trough design was tested.

The new trough design was essentially a groove running down the center of the spreading table (see Figure 7, page 38). Although the concept was effective at guiding spreads, the spreads were difficult to make wrinkle free and difficult to keep wrinkle free. By shifting the trough location from the center of the spreading table to one edge of the spread (see Figure 8, page 39), the spread wrinkling problems were reduced.

The modified Zippy Guide worked by floating the spread with the air floatation table, moving the spread with the Zippies, and guiding the spread

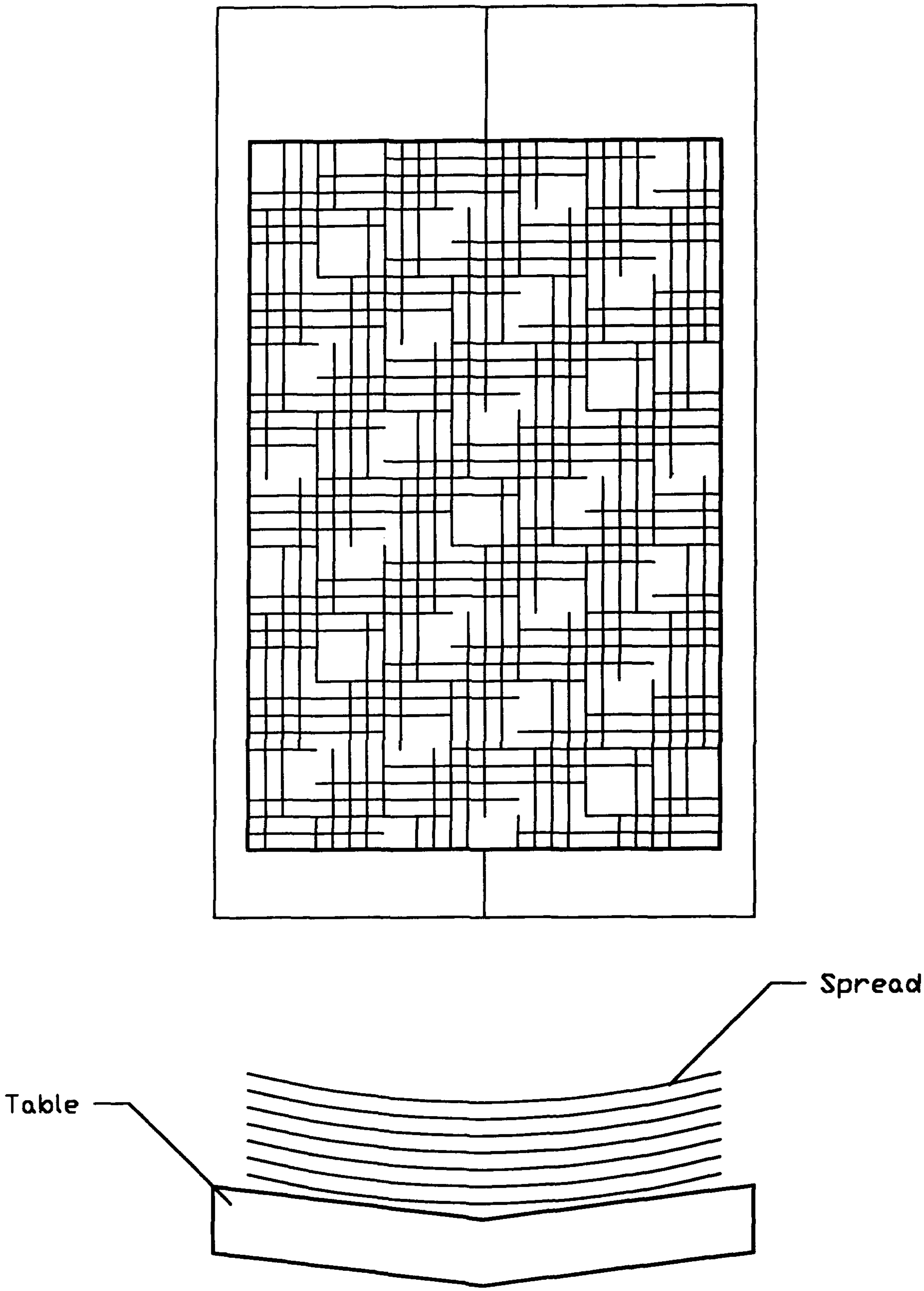
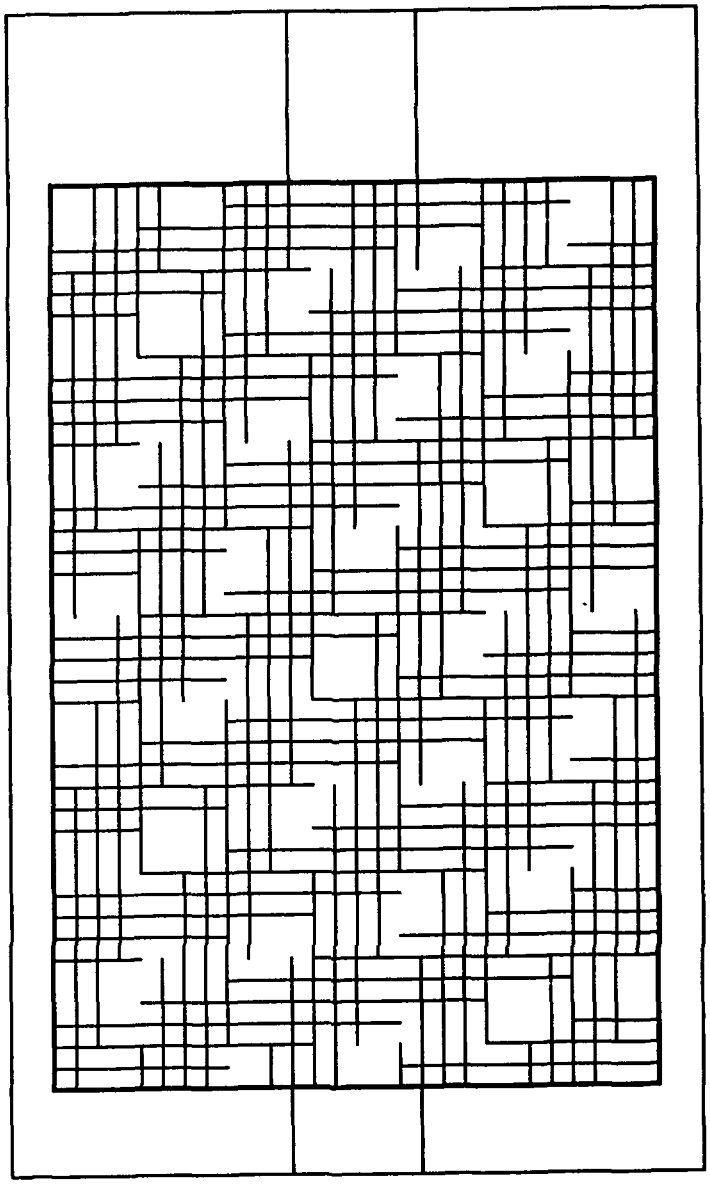


Figure 6 - "V" Trough Zippy Guide



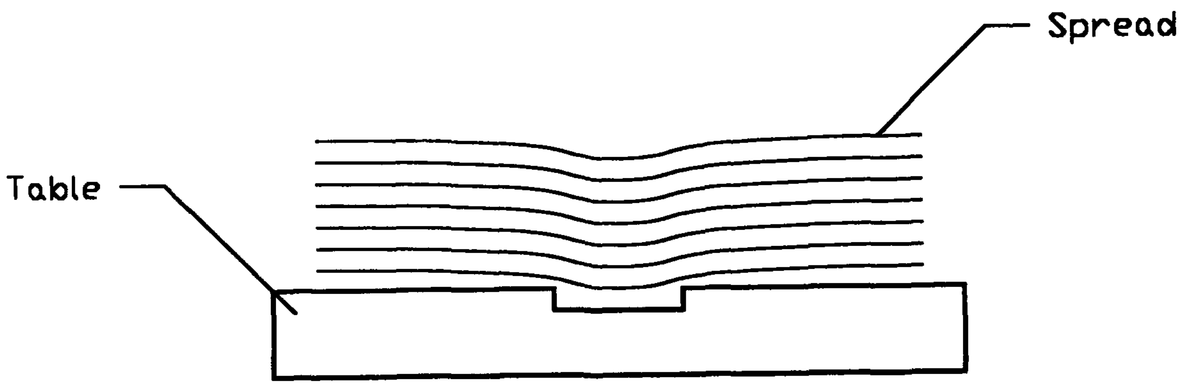
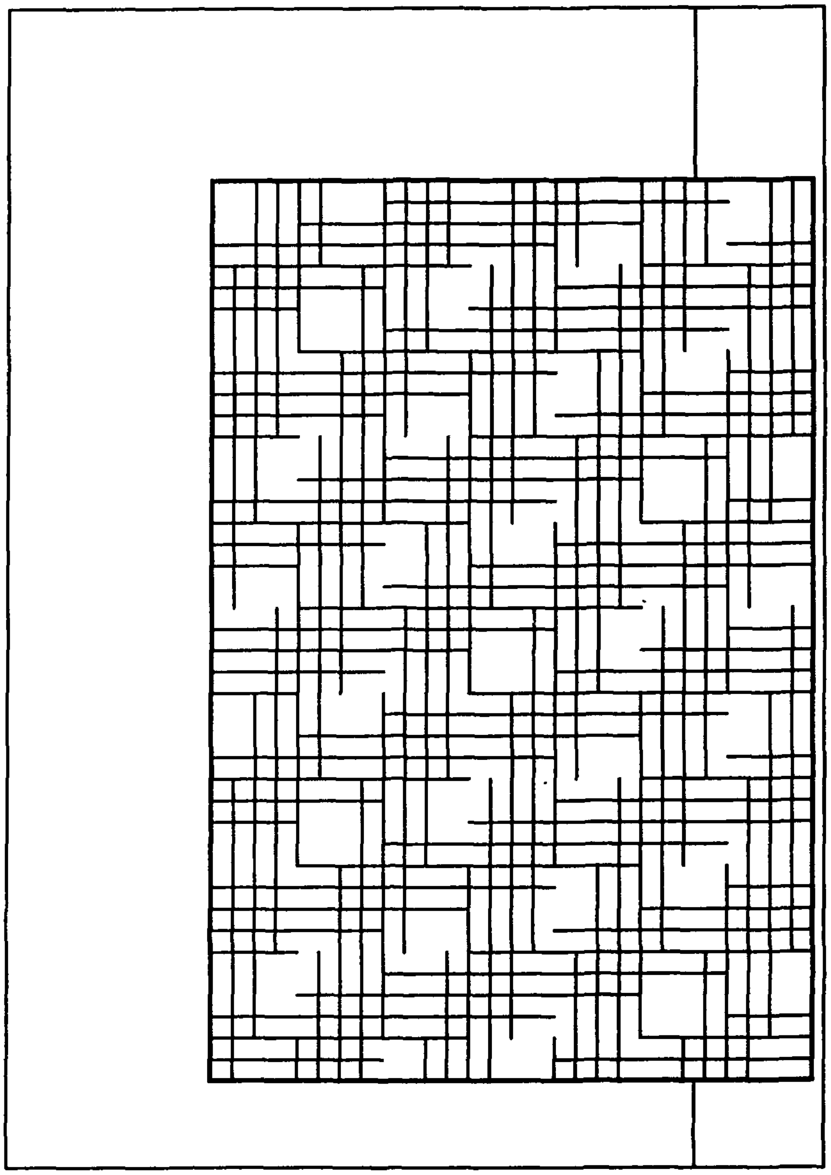


Figure 7 - "U" Trough Zippy Guide



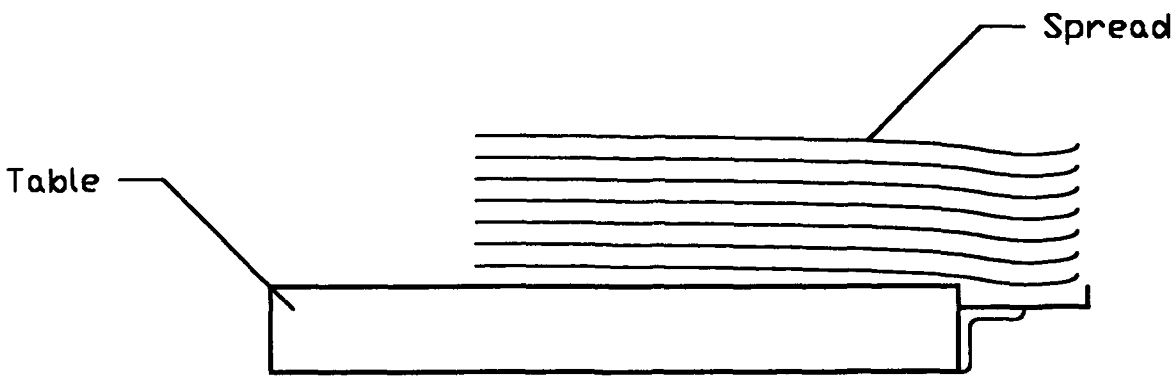


Figure 8 - Side Trough Zippy Guide

with the trough. The modified Zippy Guide concept worked well with small test spreads, but real spreads proved to be a problem.

After measuring the forces exerted by four Zippies on a four foot by four foot, 48 ply high spread made of military dress shirt material, it was estimated that moving a 200 ply, full length spread, six feet wide and 100 feet long, would require a minimum of eight Zippies per four foot by six foot air floatation table section. With each Zippy costing $80, the cost of converting a 150 foot long spreading table into a Zippy Guide table would be roughly $24,000, excluding compressed air and installation costs. Needless to say, the concept was not pursued further!

IDL Guide, Reevaluation

Recognizing that commercially available air jets did not provide a cost effective means of moving spreads, design efforts returned to the IDL Guide. As explained earlier, two of the problems encountered with the IDL Guide involved moving the spreads and keeping the spreads under tension. A solution to each problem involved clamping a tensioned tape measure to each end of the spread.

By joining both tape measures into a continuous band, and mounting a fixed clamp at one end of the band and a positionable clamp at the other, the design team was able to move spreads without buckling them. Replacing the tensioned metal band with a continuous tensioned cable (like a ski lift) made it possible to guide the spread automatically (see Figure 9, page 41). Unfortunately, just like the Woolrich Guide, the clamps prevented automatic on- and off-loading.

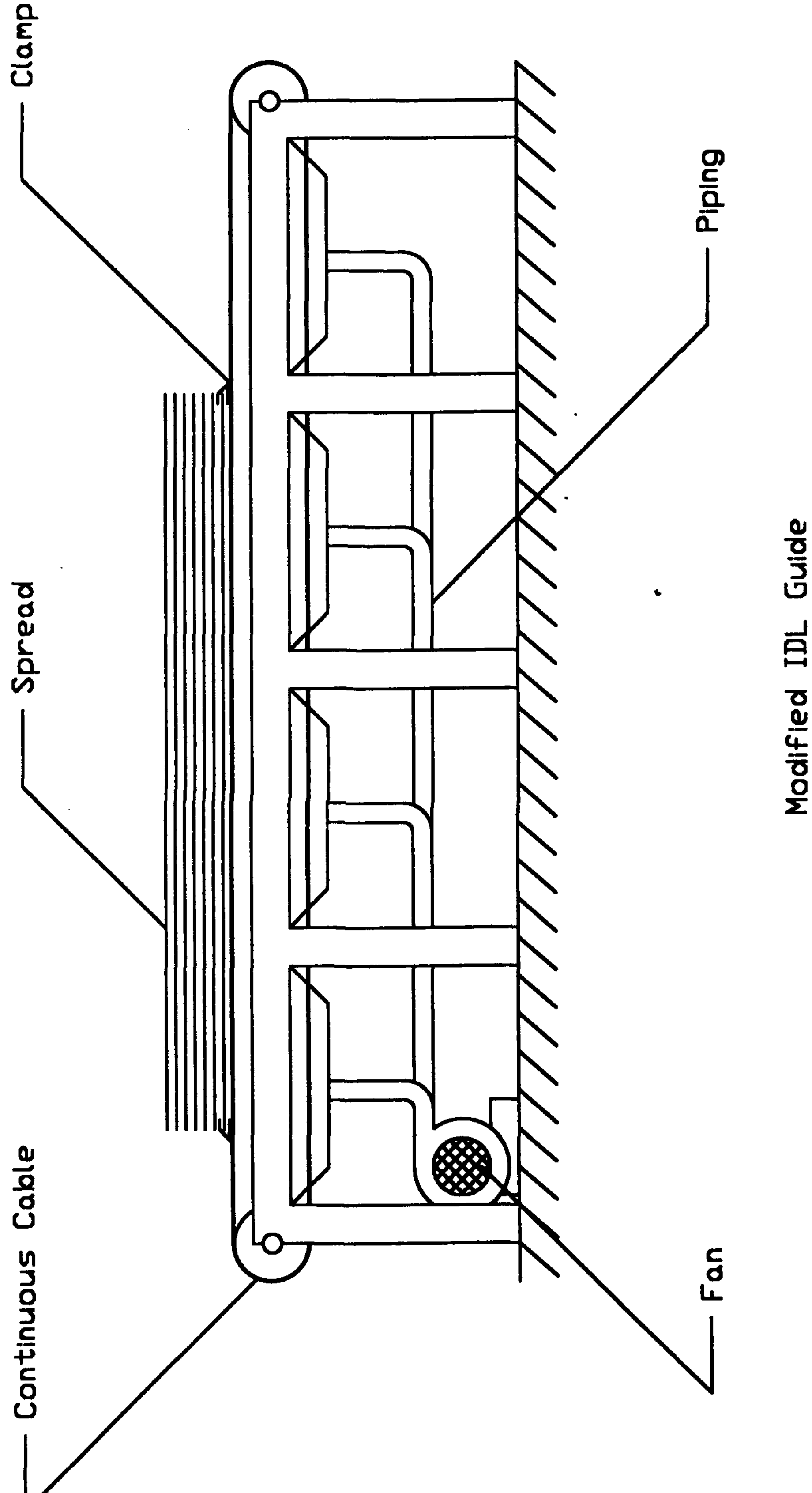


Figure 9 - Modified IDL Guide

Without the clamps, the tensioned cable could just move small test spreads. The Design team reasoned that replacing the thin, round, metal cable with a flat rubber belt would allowed the Modified IDL Guide to work much better. As a result, the Belt Guide was formed (see Figure 10, page 43).

Belt Guide, Preliminary Investigation

To evaluate the potential of the Belt Guide concept several basic questions had to be answered:

- Would a Belt Guide work?
- How much would a Belt Guide cost?
- Would customers buy Belt Guides?

To answer the above questions the following points had to be addressed.

- Where should the belt be located?
- What material(s) should the belt be made of?
- How big did the belt need to be?
- What type of drive system would be best?
- How big did the drive motor need to be?

Would a Belt Guide Work?

Full-width conveyer-bed spreading-tables are commercially available. Full width belts are unnecessary because the spread-to-table friction forces on air floatation tables are minimal. On air floatation tables the belt only needs to be wide enough to provide friction forces equivalent to the pulling forces a single man can exert. To avoid the unnecessary costs associated with a full width conveyor, the Belt Guide uses a narrow belt.

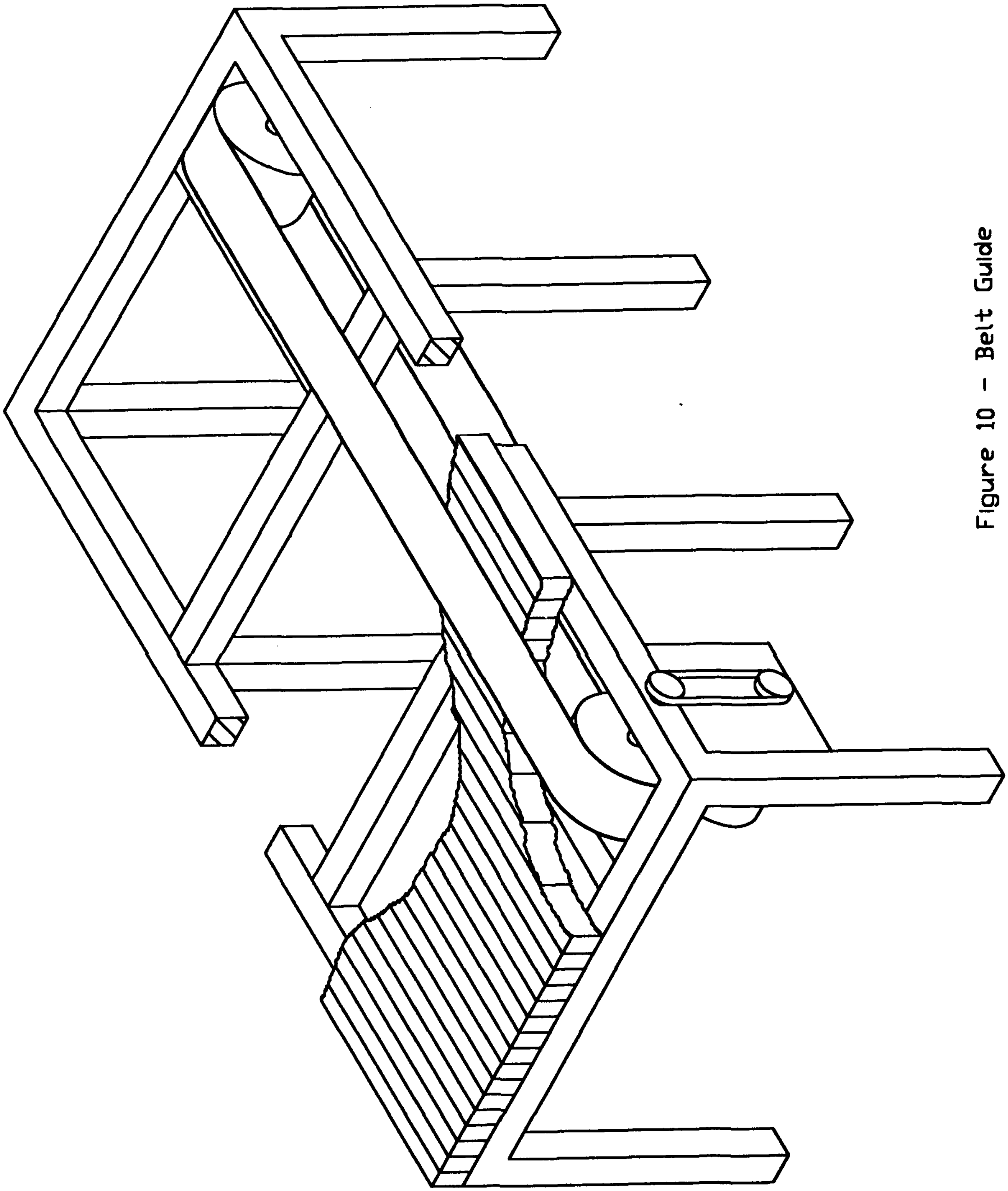


Figure 10 - Belt Guide

Figure 10 - Belt Guide

Where should the belt be located?

There were several reasons to locate the belt on one side of spreading table. The first reason involved maximizing spread-to-belt friction forces. On almost all commercially available air floatation tables, and on most home-made air flotation tables, the air floatation holes are located away from the edges of the air floatation table. Locating the holes away from the table edges insures that most of the air being delivered to the table will be delivered under the spread helping to lift the spread. Placing the belt in the center of the spreading table, where the floating forces were greatest, minimized the spread-to-belt friction forces. However, placing the belt on the edge of the spread maximized the spread-to-belt friction forces. Also, placing the belt on the reference edge side of the spread minimized the risks of damaging the reference edge during air floatation.

What material should the belt be made of?

To minimize the belt's impact on other aspects of cutting room operations, efforts focussed on finding the smallest belt possible that would still safely move a majority of spreads. Fortunately, in all CNC cutting operations perforated spreading paper is used as the first ply of spreads. The paper ensures that during cutting the bottom-most cut pieces do not bend and are not pushed into the cutting table's bristle bed. By obtaining samples of commercially available spreading paper, and selecting the "slickest", a spread frictional-reference was established. Since the Belt Guide only comes into direct contact with the spreading paper, selecting the "slickest" paper established a worst case spread-to-belt friction scenario.

After evaluating the paper-to-belt frictional characteristics of a large number of belt materials two high quality, high coefficient of friction belts were selected for additional testing. Both belts have slick, heavy-duty backings to ensuring that they slide smoothly on the spreading table surface. The more expensive belt has a smooth top surface. The less expensive belt had a surface with a higher coefficient of friction, but the surface is slightly grooved. After considerable debate, the design team decided to adhere to the HOQ suggestion that the cost of the guide be kept low, and the grooved belt was selected for additional testing. The next step in the Belt Guide design was to select a belt width.

How big did the belt need to be?

Choosing a belt width proved difficult. The cost of the belt material and it's high coefficient of friction encouraged selection of a narrow belt width. CAR's use of limited spread sizes and material compositions also encouraged narrow belt selection. Industry spread variations, on the other hand, encouraged the selection of a belt large enough to handle the largest of spreads. The design team reasoned that, with the air floatation table turned on, as long as the frictional forces between the spread and the belt were higher than the friction forces between the spread and the table, the belt would move the spread. Simple design calculations supported the design team's assumptions.

By definition, the frictional forces exerted between objects is a function of the coefficient of friction between the objects and the forces the objects exert on each other. In mathematical terms,

Eq. 1

$F_{friction} = F * \mu_{static}$

Where

$F_{friction}$ = The resulting frictional force

F = The force exerted between the objects

μ_{static} = The coefficient of static friction between the objects

In the case of spreads, the forces exerted are a function of the weight per unit area of the spread and the area of surface contact with the spread. Expressed as an equation,

Eq. 2

$F = W_{per\ unit\ area} * A_{contact}$

Where

F = The force exerted between the objects

$W_{per\ unit\ area}$ = The total weight of the spread divided by the product of the length and width of the spread

$A_{contact}$ = The area of contact between the spread and surface of interest

As long as the frictional forces between the spread and the belt are higher than the friction forces between the spread and the table, the belt will move the spread. In mathematical terms, the belt size is large enough if,

Eq. 3

$$F_{friction_{belt}} > F_{friction_{table}}$$

Combining Equations 1 and 3 produces

Eq. 4

$$F_{belt} * \mu_{static_{belt}} > F_{table} * \mu_{static_{table}}$$

Substituting Equation 2 into Equation 4 gives

Eq. 5

$$W_{per\ unit\ area} * A_{contact_{belt}} * \mu_{static_{belt}} > W_{per\ unit\ area} * A_{contact_{table}} * \mu_{static_{table}}$$

Substituting length and width measurements for $A_{contact_{belt}}$ and $A_{contact_{table}}$ and canceling $W_{per\ unit\ area}$ on both sides of Equation 5, yields

Eq. 6

$$L_{contact_{belt}} * W_{contact_{belt}} * \mu_{static_{belt}} > L_{contact_{table}} * W_{contact_{table}} * \mu_{static_{table}}$$

Where

L = Length

W = Width

Since the contact-length of spread with the belt and the contact-length of spread with the table are both equal to the length of the spread, Equation 6 can be rewritten as

Eq. 7

$$W_{contact\ belt} * \mu_{static\ belt} > W_{contact\ table} * \mu_{static\ table}$$

Expressing Equation 7 in words; if the width of the belt times its coefficient of friction with the spread is greater than the width of the table, in contact with the spread, times the table's coefficient of friction with the spread, the belt will pull the spread. It is important to note that the coefficients of friction in Equation 7 are dependent on the belt and table characteristics alone. This is because both surfaces are being compared to the same contact surface, i.e. the spreading paper.

What Equation 7 shows is that the pulling characteristics of the Belt Guide is independent of all spread characteristics except spread width. The material the spread is made of is not important. The number of plies in the spread is not important. Even the length of the spread is not import.

To test this design conclusion, the design team constructed two spreads at opposite ends of the spread spectrum. The first spread was a 48 inch wide, 16 foot long, 48 ply spread of military dress shirt material. The second spread was a 72 inch wide, 16 foot long, 200 ply spread of 14oz. denim. The reason the spreads were 16 feet long is because of CAR's small spreading table size. After conducting a number of tests, it was determined that moving the denim required a minimum belt width of eight inches. Moving the military fabric required a minimum belt width of two and a half inches. Since the denim spread was 72 inches wide, and a belt width of eight inches was just enough to move the spread, Equation 7 could be rewritten as

Eq. 8

$$(8")_{contact\ belt} * \mu_{static\ belt} = (72"\text{-}8")_{contact\ table} * \mu_{static\ table}$$

or

Eq. 9

$$(8")_{contact\ belt} + (72"\text{-}8")_{contact\ table} = \mu_{static\ table} + \mu_{static\ belt}$$

Since the right side of Equation 9 was a constant, Equation 9 could also be written

Eq. 10

$$(8")_{contact\ belt} + (72"\text{-}8")_{contact\ table} = (2.5")_{contact\ belt} + (48"\text{-}2.5")_{contact\ table}$$

or

Eq. 11

$$8" + 64" = 2.5" + 45.5"$$

or

Eq. 12

$$0.125 = 0.0549$$

Obviously, based on experimental data, some of the assumptions made in deriving Equation 7 were false. Equations 10 and 12 showed that the ratio of belt-contact to table-contact had to be 225% greater for the large spread than the small spread. An explanation for this stems from the fact that as the number of spread plies increases, the air permeability of the spread decreases. Since the air coming out of the air floatation table can not escape through the spread it escapes through the sides of the spread. If the belt is located on the edge of the spread, air escaping from the sides of the spread lifts the spread off the belt, and a larger belt is needed. Tests with non-air

permeable, 48" wide butyl rubber, supported this hypothesis. Since air permeability of the fabric had an affect on how well the Belt Guide worked, selecting a good belt size became a matter of trial and error.

The design team felt that making, testing, and demonstrating a Belt Guide with all it's potential features was a more intelligent machine development approach than producing a non-viable guide concept. To select the final belt size, the design team chose the largest belt that would nearly move CAR's 48 ply, 16 foot long, military spreads with the air floatation table turned off. The design team reasoned that if the belt could not move a spread with the air floatation off, one spread could be made while another spread, on a section of air table that was on, could be moved. Essentially, one belt could run the entire table length and still allow simultaneous spreading and cutting. As a result of the design team's tests, a final belt width of three inches was selected.

What type of drive system would be best?

The next step in evaluating the Belt Guide concept involved selecting a basic drive system. To make the drive system flexible, durable, and low cost, DC servo motor technology was viewed as the best drive system technology. With numerous control options including high starting torque, adjustable acceleration ramp, variable speed control, and forward and reverse direction control, DC servo drives offer complete design and test flexibility in a reliable and affordable package. The design team felt that connecting the motor with gear-belts and pulleys, both available in a large variety of sizes, would allow pulling performance of the belt guide to be tuned to specific performance requirements.

How big did the drive motor need to be?

To ensure that the motor was powerful enough to move spreads at least as fast as a human, calculations were made to determine the horse power required to accelerate a 1000kg (2204lb) spread at $0.5 m/sec^2$ ($1.64 ft/sec^2$) to a maximum velocity of 0.5m/sec (1.64ft/sec). The calculations are discussed below, beginning with the definition of power,

Eq. 13 $$P = W \div t$$

Where: P = power, W = work, and t = time

Defining work,

Eq. 14 $$W = F * d$$

Where: F = force, and d = distance

Defining force,

Eq. 15 $$F = m * a_0$$

Where: m = mass, and a_0 = initial acceleration

Defining distance in Equation 14

Eq. 16 $$d = x - x_0$$

Where: x = finishing point, and x_0 = ending point

Defining finishing point,

Eq. 17 $$x = x_0 + v_0 t + 0.5 a_0 t^2$$

Where: v_0 = initial velocity

Defining initial velocity,

Eq. 18 $$v = v_0 + a_0 t$$

Where: v = final velocity

Setting $v_0 = 0$ and rearranging Eq. 18 resulted in

Eq. 19 $$t = v \div a_0$$

Setting $x_0 = 0$ and plugging Eq. 19 into Eq. 17 yielded

Eq. 20 $$x = 0.5a_0(v \div a_0)^2$$

Rearranging Eq. 20

Eq. 21 $$x = v^2 \div 2a_0$$

Remembering that $x_0 = 0$, and plugging Eq. 21 into Eq. 16 produces

Eq. 22 $$d = v^2 \div 2a_0$$

Substituting Eq. 22 and Eq. 15 into Eq. 14 and rearranging gives

Eq. 23 $$W = mv^2 \div 2$$

Substituting Eq. 23 into Eq. 13 gives

Eq. 24 $$P = mv^2 + 2t$$

Substituting Eq. 19 into Eq. 24 and rearranging produces

Eq. 25 $$P = mva_0 + 2$$

Plugging in the original values

m = mass of spread = 1000kg

v = final spread velocity = 0.5m/sec (max.)

a_0 = initial spread acceleration = 0.5m/sec^2 (max.)

Yielded

$P = 125\ \text{kg}\cdot\text{m/sec}\cdot\text{m/sec}^2$

$= 125\ \text{kg}\cdot\text{m}^2/\text{sec}^3$

= 125 Watts

= 0.167 Horse Power

Calculations indicated that a 1/4 (0.250) horse power servomotor was big enough to handle a majority of spread moving requirements.

How much would a Belt Guide cost?

With all the basic design information in hand, the design team recognized that the initial cost of a Belt Guide design would be much higher than any of the other industry guide designs. Shopping for the best prices on all of the major Belt Guide components, and taking advantage of Original Equipment Manufacture (OEM) discounts offered by many suppliers, the design team placed the cost of a finished Belt Guide at $2020.

Cost Analysis

Would customers buy Belt Guides?

Since the QFD analysis indicated that ease of purchase was foremost on the customer's mind, the customer requirements of a 24 month payback and a low initial cost would be major stumbling blocks for the Belt Guide. Taking modest installation costs and labor savings into account, the design team felt that customers could be persuaded to overlook the relatively high initial cost of a Belt Guide and focus on the machine payback instead. (In the HOQ the sales points column shows the strongest sales points of the Belt Guide as two concentric circles, and modest sales points as single circles.) The customer requirement of a 24 month payback was less easy to overlook. However, as explained on page eleven, apparel/textile customers use a 24 month payback schedule as a means of simplifying cost analysis and to guarantee a quick return on investment (ROI). (ROI is a cost analysis technique that takes into account the time value of money. Simple payback analysis does not take into account the time value of money and, though easy to use, payback analysis is generally inaccurate.)

By providing the customer with easy to use, but comprehensive, cost versus savings information, the design team felt that the firm customer requirement of a 24 month payback could be bent to include a 36 month payback. The design team reasoned that providing the customer with an easy means of evaluating a Belt Guide purchase would satisfy the customer requirement of easy cost justification, while establishing the production environment in which a Belt Guide would be cost effective.

Providing customers with comprehensive, yet easy to use information, based on a truly complete cost analysis, was a daunting task. Fortunately alliances with CAR and the Clemson College of Commerce and Industry have produced AMCIA (the Apparel Manufacturer Capital Investment Advisor). AMCIA is a program used by apparel customers to justify equipment purchases. The program is comprehensive, taking into account virtually every conceivable factor influencing apparel related ROI's. (For detailed information about AMCIA contact Clemson Apparel Research, 803/646-8454). Using general information provided by Mr. Ed Hill, CAR's Site Director, the design team established relationships between time, cost savings, and production rates that would provide both a 24 month ROI and a 36 month ROI. A detailed list of all the AMCIA inputs is in Appendix F and AMCIA output values are in Appendix G. In raw form the information produced by AMCIA was difficult to digest. By converting the comprehensive information into graphs, estimating the Belt Guide's ROI became straight forward.

Two graphs were produced. The first graph (see Figure 11, page 56) plots the relationships between time and cost savings and the production rates necessary for a 24 month ROI. The second graph (see Figure 12, page 57) plots the relationships between time and cost savings and the production rates necessary for a 36 month ROI. Both graphs are based on the assumption that a work year is 49 weeks, five day weeks, and that each spread contains enough parts for 2400 finished assembled units. To best explain the graphs, several examples were formulated.

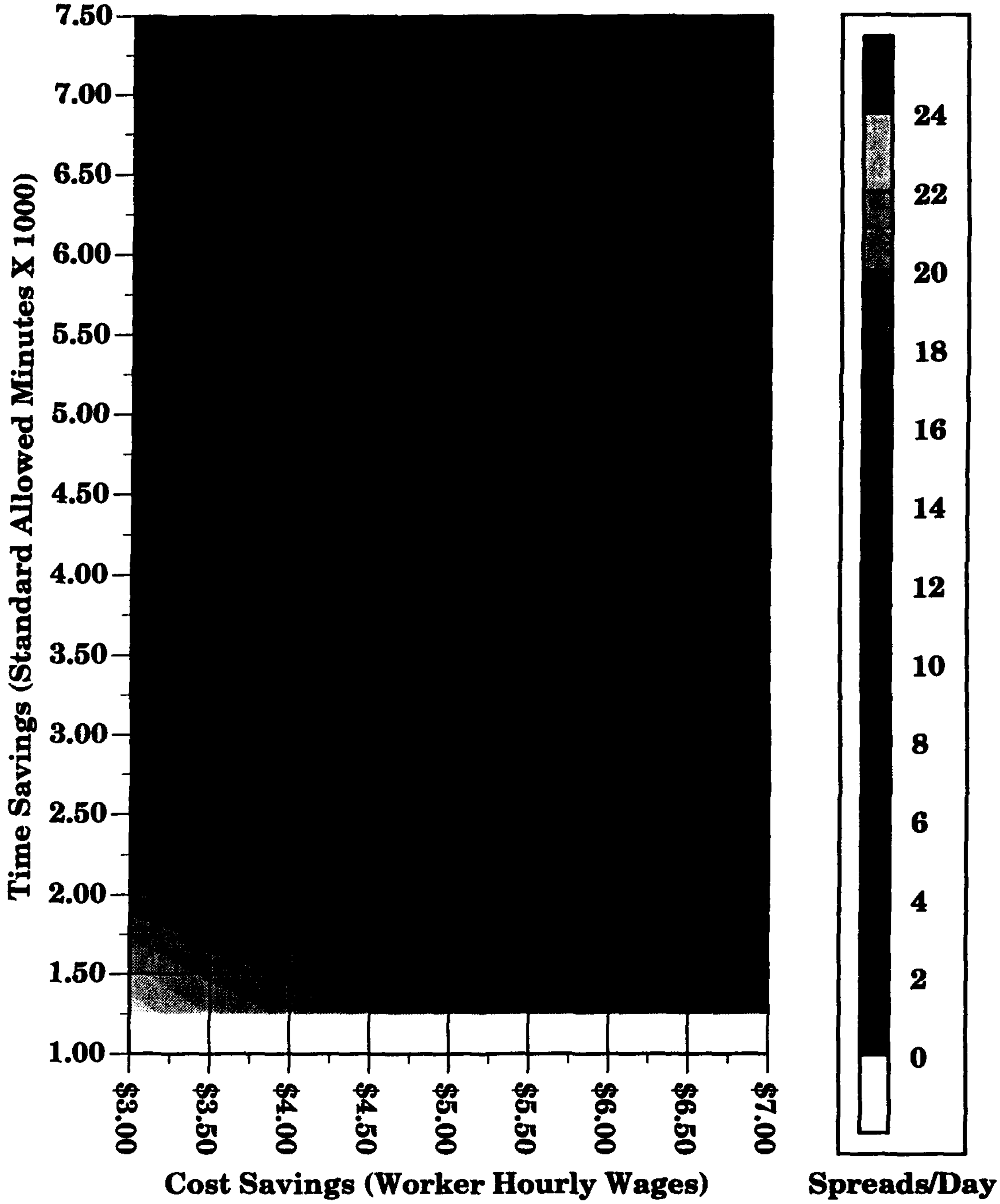


Figure 11 - AMCIA 24 Month Payback Graph

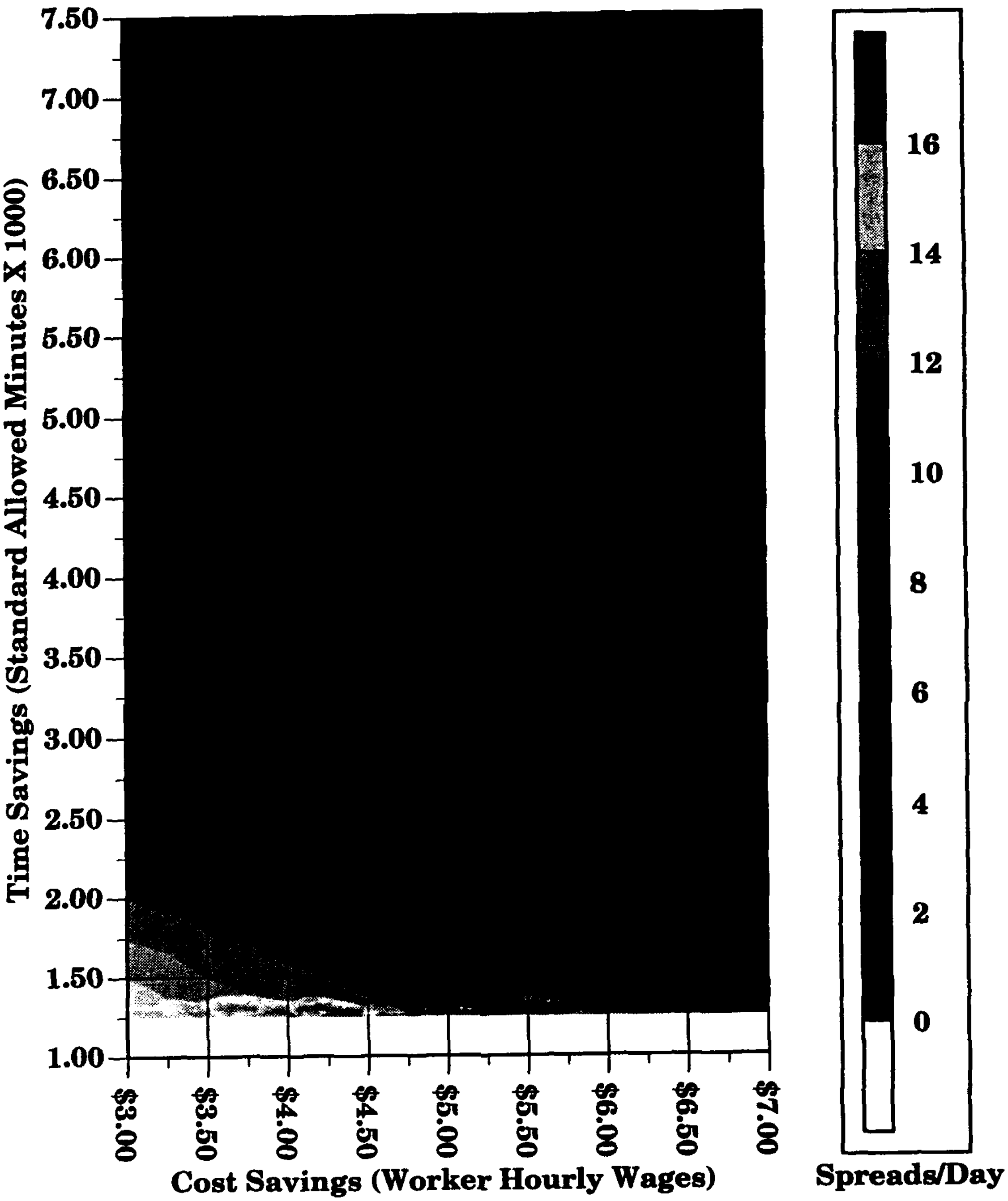


Figure 12 - AMCIA 36 Month Payback Graph

Using Figure 11, on page 56, for the first example: If a customer pays his cutting room employees an average of \$5.50 per hour, and the customer estimates that completely automatic spread floatation will save $3 \div 1000 = 0.003$ Standard Allowed Minutes[4] (SAM's) per complete assembly, then to recognize a 24 month Belt Guide ROI requires the customer to produce between 4 and 6 spreads per day, five days a week, 49 work weeks a year, assuming that each spread contains enough parts to produce 2400 assembled units. If, on the other hand, the customer pays his cutting room employees an average of \$4.50 per hour, with all other factors held the same, 6 to 8 spreads per day are required for a 24 month ROI.

Using Figure 12, on page 57, for the second example: If a customer pays his cutting room employees an average of \$5.50 per hour, and the customer estimates that completely automatic spread floatation will save 0.003 SAM's per complete assembly, then to recognize a 36 month Belt Guide ROI requires the customer to produce between 2 to 4 spreads per day, five days a week, 49 work weeks a year, assuming that each spread contains enough parts to produce 2400 assembled units. If the customer paid his cutting room employees an average of \$4.50 per hour, with all other factors held the same, 4 to 6 spreads per day are required for a 36 month ROI.

In general terms, as the hourly employee wages drop, and the estimated time savings drop, production volumes have to increase in order to justify the cost of a \$2020 Belt Guide. On the other hand, if the hourly employee wages are high, and the estimated time savings are also high, large production volumes are not required for 24 to 36 month ROI's. The two

graphs allow customers to quickly estimate the production capacities necessary to justify the cost of a Belt Guide.

To the design team, the cost analysis indicated that if companies are able to justify the typical $150,000 cost of CNC cutters, their production volumes are high enough to meet a 36 month ROI on a Belt Guide, and in many cases their production volumes are high enough to meet a 24 month ROI. With this information in hand, the design team proceeded with the competitive evaluation section of the House of Quality (HOQ).

Comparison of New versus Existing Guide Designs

With several guide design-alternatives in hand, the design team continued with the QFD analysis by comparing the guide design-alternatives with existing guide designs (see Table 4, below).

Table 4 - Competitive Guide Comparisons

(Based on Customer Requirement Weights)

Guide	Total Score
Belt	120
S&S	110
Oxford	101
IDL	100
Planned Performance Level	99
Woolrich and Zippy	93

Placing the Zippy, IDL, and Belt Guide designs in the HOQ and evaluating each with respect to Customer Requirement Weights, the Zippy Guide scored even with the Woolrich Guide, while the IDL Guide Scored one point lower than the Oxford Guide. The Belt Guide scored 120 making it the best alternative to pursue. Originally, with no specific competitive concepts in hand, the guide designers had adopted a conservative planned performance level of 99. The Belt Guide concept gave the design team an opportunity to significantly improve air floatation guide technology.

FINAL GUIDE DESIGN, INSTALLATION, TESTING, AND DEMONSTRATION

Final Guide Design

Having nearly completed the HOQ and with a reasonable cost analysis in hand, the design team decided to continue development of the Belt Guide. Since most of the critical design parameters were established during the preliminary cost analysis, the design team did not have to perform extensive design modifications. Instead, the design team's efforts turned to specifying part parameters in mechanical drawings and then to acquiring the parts necessary to build a prototype Belt Guide. (As explained in the introduction, detailed drawings of the final Belt Guide design cannot be submitted in this report due to on-going patent efforts.)

Because, like many apparel plants, CAR did not have machine tools, and because gaining access to the Engineering Department's tools was difficult and costly, only a few of the final part designs required machining. Most of the final parts are commercially available including the crowned drive and idler pulleys (crowned pulleys were used to ensure that the belt would be self-centering even under heavy cross loads).

The only assemblies of the Belt Guide that required machined parts were the belt tensioning assembly, the belt drive-shaft assembly, and the drive-motor/control-panel mounting assembly. The frame assembly was manufactured at CAR using square metal tubing, a power drill, a jigsaw with metal cutting blades, and a small oxyacetylene welding torch. These tools can be found in most modestly equipped apparel plants.

Guide Installation

With all of the pieces in hand, the design team cut and routed two 4" X 4" holes in either end of the spreading table, drilled and tapped bearing mount holes into the existing table frame-work, installed the additional framework to support the belt pulleys, and mounted and wired the drive controls next to the existing air floatation table on/off switch. The final step in installing the guide involved threading the belt and bonding the ends together.

An obscured image of the final Belt Guide shows the belt moving a spread from underneath a spreading buggy (see Figure 13, below).

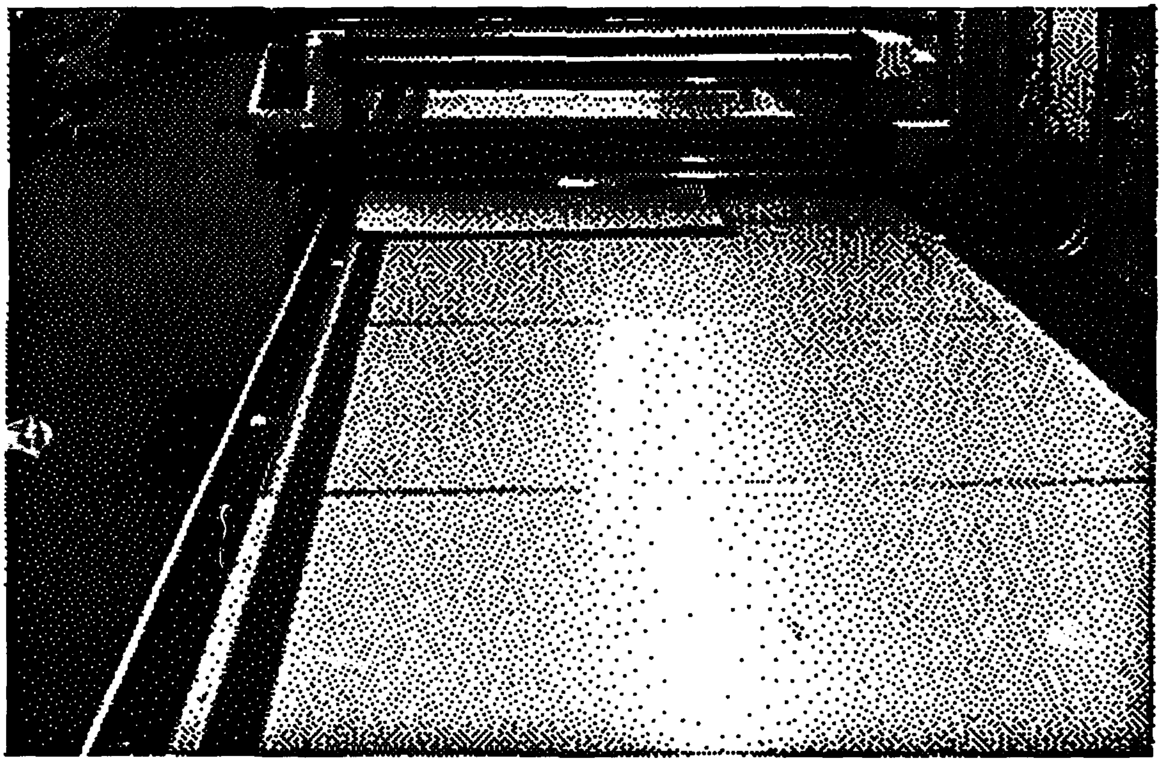


Figure 13 - Scanned Photo of Actual Belt Guide

The air floatation table is white. The Belt Guide runs down the left-hand side of the table a short distance from a black metal edge which serves as

the spreading-buggy guide-rail. At the top of the photograph is the lower half of the spreading buggy. Moving away from the viewer (you), and just about to pass underneath the spreading buggy on the left hand side of the spreading table, is a 48 ply high 48" wide spread.

Guide Testing

Once the guide was installed, tests were conducted to gage how well the guide performed. According to Mr. Jim Gooch, CAR's spreading expert, the Belt Guide works well. Narrow spread widths work best, but full width spread can also be moved. The only spreads which do not work well are heavy, full-width spreads, with poor air permeability. These types of spreads can be moved by the Belt Guide, but only if weights are placed on each end of the spreads pressing the spreads onto the belt. The weights ensure that the spreads do not skew. Once the front ends of the spreads have reached the cutter, and are under vacuum, the weights can be removed.

Based on the preliminary performance evaluation, the design team completed the HOQ by filling in the Technical Comparison section. This section shows that, for spreads typically produced at CAR, the Belt Guide meets all of the major technical requirements derived from initial customer requirements. Base on the completed HOQ evaluation the design team felt the Belt Guide design was a technical success. The design team did not know if the Belt Guide was a commercial success, however. To determine how well the Belt Guide would be received by industry, the design team and Mr. Gooch demonstrated the guide.

Guide Demonstration

Demonstrations of the guide, to individuals who signed non-disclosure agreements, led to several inquiries regarding the purchase of Belt Guides (one of the requests came from an Oxford Industry cutting room manager). Industry interest in the Belt Guide came mainly from personnel in large cutting room operations. Unfortunately, CAR's cutting operation is not large enough to produce industry size test spreads, and so it is not known, for certain, how well CAR's Belt Guide will work in an industry setting. Positive responses from the apparel and textile industries support the design team's conviction, that although the guide is not perfect, it paves the way for future commercial air floatation guide tables in which Belt Guides are an integral part.

RECOMMENDATIONS

As explained in the Guide Testing section on page 63, the Belt Guide did not work well on full-width spreads. A description of the Belt Guide's performance problems, and associated hypotheses explaining the performance problems are given below.

The Belt Guide suffered from two major problems

- The belt interfered with manual cutting

and

- The belt could not prevent full width spreads from skewing

The interference problem became apparent when the belt was accidentally slit by a manual knife cutter.

Manual cutting machines come in a variety of designs, but they share a common feature. To cut through the bottom-most spread layers, the machines have a tapered metal plate with recessed grooves into which the cutting blade moves. The wedge shaped metal plate, or foot, slides along the spreading table surface lifting the bottom most spread layers so that the cutting blade can pass through the bottom layers without damaging the spreading table. Unfortunately, like spreads, the Belt Guide rested on the table surface. The foot of the manual knife cutter slid under the belt allowing the knife to cut the belt.

To avoid the risk of cutting the belt, future Belt Guides should be slightly, or fully, recessed into the spreading table, or should have belt-length, thin,

tapered wedges, of material placed in front of the belts' edges. Either solution will ensure that the manual cutter feet are directed over the guide belt surfaces rather than under the guide belt surfaces. Selection of a solution depends on whether a guide is to be an integral part of a new spreading table or a retrofit part of an old spreading table. In either case, the solutions are straight forward and should be easy to execute. The second Belt Guide problem of spread skew is more difficult to solve, however.

As explained on page 44, the Belt Guide belt was located on one outside edge of CAR's spreading table to maximize spread-to-belt friction forces. Unfortunately, the same physical characteristics that increase spread-to-belt friction forces on one side of the spread, increase spread-to-table friction forces on the other side of the spread. So, when the belt moves, one side of the spread moves with the belt, while the other side wants to stick to the table. The net result is that all spreads are subjected to a "force couple" that wants to twist or skew the spreads. The further apart the edges of the spread are, the greater the skewing forces. Hence, full width spreads tend to skew.

As explained on page 50, the design team selected a belt size that would move most of the spreads made at CAR while demonstrating the concept that while one spread was being moved, another spread could be made without being moved. Since there was no data available to suggest otherwise, the design team made the most intelligent decision possible with the information available, and that decision was to develop a guide that

could be fully demonstrated at CAR. In retrospect, there are two ways to solve the full-width-spread skewing problem, however.

- Make the existing belt wider

and/or

- Install a second belt on the other side of the spreading table.

Based on the test described on page 50, making the belt much wider would move small spreads even when the air floatation table was turned off. A preliminary problem-solving investigation by the design team showed that if the current three inch wide belt was moved approximately 60 inches into the table, and the current belt location was modified to accommodate a four inch wide belt, the guide could move all spread sizes while maintaining most, if not all, of the current technical performance features. A major problem confronting such new designs involves maximizing the performance/price ratio, however.

Using this report's QFD analysis as a guide to making design changes, while conducting associated AMCIA cost analyses to determine viable cost options, a maximum performance/price ratio for a range of industrial Belt Guide designs could be found. The work done on the Air Floatation Guide Project shows that it is possible to build an inexpensive, automated, spread-guiding, system for air-floatation spreading-tables. What commercially viable design options are in the apparel/textile industry's future remains to be seen, however.

NOTES

1. Daniel, Robert Keith, and Clapp, Dr. Timothy G., "Enhance the Commercial Acceptance of an Automatic Ply Separation & Feeding System for Apparel Fabrics", North Carolina State University School of Textiles, Raleigh, NC, Oct. 28, 1991.

2. Daniel, Robert Keith, and Clapp, Dr. Timothy G., "Enhance the Commercial Acceptance of an Automatic Ply Separation & Feeding System for Apparel Fabrics".

3. Definition: Snap-back
   A condition that occurs when fabric, stored under tension (usually in rolls), returns to its tension free state (usually in a spread). Synonym: Hysteresis.

4. Definition: Standard Allowed Minutes (SAM's)
   The total amount of time spent by an employee(s) to process a complete production unit. Example: Without the Belt Guide two employees would have to spend a minimum of three minutes each to set up a spread for CNC cutting. If the spread contained enough parts to make 2400 complete products, the SAM's used to guide the spread would be

$$\frac{3 \text{ employees } \times 3 \text{ min./employee}}{2400 \text{ units}} = 0.00375 \frac{\text{min.}}{\text{unit}} = 3.75\text{E-03 SAM's}$$

APPENDIXES

Appendix A - Desired Air Floatation Guide Features

The guides are inexpensive in every aspect
- Inexpensive to manufacture
  - The guides can be retrofit to any air-floatation table,
  - The guides do not interfere with the spreading operation,
- Inexpensive to install
  - The guides can be retrofit to any air-floatation table
  - The guides are inexpensive in every aspect,
  - Can accommodate existing equipment deficiencies
    - The guides must accommodate the uneven surfaces and edges inherent to all spreading table surfaces.
  - Does not require table modifications
  - Easy to retrofit
  - Does not interfere with spreading
  - Does not interfere/conflict with existing spreading methods
- Easy to locate
  - The guides can be retrofit to any air-floatation table,
  - Easy to position
  - Can be positioned reliably
  - Easy to move
  - Can be moved from one table to the next
  - Compact construction
- Inexpensive to use
  - Does not interfere/conflict with existing spreading methods
    - The guides should have a recess to accommodate spreading paper so that the spreading paper does not interfere with the operation of the guides and so that spreading techniques do not have to be modified.
- Does not interfere with normal spreading
- The guides can be retrofit to any air-floatation table,
- Does not require operator intervention to off-load
  - The guides should unclamp automatically as they are pulled towards the cutter so that the person operating the cutter can bundle pieces instead of monitoring the guides.
- The guides do not interfere with manual cutting
- Does not require operator intervention to on-load

The guides should clamp automatically so that the person(s) spreading material can finish a spread without having to go back along the spread to place the air guides.

Minimize spread distortion

The guides should offer minimum frictional resistance so that spread distortion is also minimized.

The guides minimize spread distortion,

Minimizes risk of spread skewing

No individual is required to monitor the system,

Does not require operator intervention

Does not interfere with automatic spreading

The guides do not interfere with the spreading operation,

Does not require spreading method modifications

Easy to move

Easy to position precisely

Does not interfere with walkways

Can accommodate existing equipment deficiencies

The guides must accommodate the uneven surfaces and edges inherent to all spreading table surfaces

Another list of general features

No individual is required to monitor the system,

The guides are inexpensive in every aspect,

The guides can be retrofit to any air-floatation table,

The guides do not interfere with the spreading operation,

The guides minimize spread distortion,

The guides do not interfere with manual cutting

Appendix B - Customer Requirements

- Inexpensive to purchase
  - Low cost
  - Easy to cost justify
- Inexpensive to install
  - Easy to understand
  - Minimum technical training required
  - Easy to retrofit
    - Easy to locate
    - Easy to position
    - Easy to move
  - Does not require table modifications
  - Does not interrupt spreading/cutting operation
- Inexpensive to use
  - Saves on labor
    - Does not require operator intervention/supervision
    - Easy to move
    - Easy to position
  - Improves quality of cut parts
    - Minimizes spread distortion
    - Precise
    - Accurate
  - Saves time
    - Easy to understand
    - Easy to use
    - Fast
    - Precise
    - Accurate
    - Does not interfere/conflict with existing spreading/cutting (both manual and automatic)methods and/or equipment
  - Does not interfere with walkways
- Inexpensive to maintain
  - Low maintenance
  - Easy to clean
  - Not affected by fabric contaminants (thread, dust)
  - Easy to fix
  - Easy to understand
  - Easy to get spare parts
  - Robust
  - Reliable

Appendix C - Original Technical Requirements

- Inexpensive to purchase
  - Inexpensive to manufacture
    - Simple parts
    - Commercially available components
    - Inexpensive parts
    - Easy to assemble
  - Comes with cost analysis (AMCIA)
- Inexpensive to install
  - Functionally intuitive
  - Good manual
  - Easy to retrofit into any cutting operation
    - Not sensitive to table configurations
    - Not sensitive to spreader configurations
    - Not sensitive to manual cutting
    - Not sensitive to automatic cutting
    - No special power/air requirements
    - Can readily interface with existing table and cutter controls
    - Easy to locate datum
    - Easy to secure
      - Simple assembly
        - No welding
        - No gluing
        - Common fasteners
      - Light Weight
    - Easy to position
      - Adjustable
        - Oversized holes
        - Slots
        - Single reference points
    - Easy to remove
      - Simple assembly
        - No welding
        - No gluing
        - Common fasteners
      - Light weight
  - Does not require table modifications
    - No affect on top of table
      - No holes
      - No grooves
    - No affect on space under table
      - Small space requirements
      - No blocking of under-table storage
    - No affect on table structure
      - No major structural changes
        - No additions

- No subtractions
- Realignments

Simple assembly

- No welding
- No gluing
- Common fasteners

Does not disrupt on-going operation

- Set-up done prior to installation
- Quick install
- Installed in isolated segments (dodges on-going work)

Inexpensive to use

- Eliminates people
    - Minimal human supervision
        - Automatic/Semi-automatic On- and Off-loading
    - Minimal human effort
        - Guide provides motive forces
        - Guide self aligns
- Better cutter output
    - No spread wrinkles
    - No edge distortion
    - No snap-back (stretching/contracting)
    - No spread misalignment
- Moves more spreads faster
    - Functionally intuitive
        - Major components easily identified
            - By part
            - By color
            - By location
            - By style
    - Easy to use
        - Minimal operator controls
        - Easy to understand controls
            - Visually obvious
        - Good Manual
    - Fast
        - Can move multiple spreads without interfering with ongoing spreading operations
        - Easy to adjust acceleration and velocity components
        - Minimal set-up times
    - Precise
        - Consistently feeds undamaged spread into cutter
    - Accurate
        - Spread is aligned to cutter

- Does not interfere/conflict with existing spreading methods
    - Spreading
        - Can accommodate the largest and smallest spreads
        - Accommodates spreading paper and other standard spreading procedures
        - Spreader does not have to stop spreading while another spread is cutting
        - Spreader does not have to change spread reference edge
        - Spreader does not have to avoid the guide
        - Spreading operator can move spread if cutter is not ready
        - Spreading operator has ready access to controls
    - Cutting
        - Accommodates manual cutting
        - Spread feed and alignment synchronized with automated cutter
        - Spread feed can be controlled from CNC cutter location
- When not in use guide should not interfere with
    - Walkways
    - Storage under table
    - Operations on table surface
        - Cutting
        - Spreading
    - Facility clean-up

Inexpensive to Maintain
- Low maintenance
    - Easy to clean
    - Not affected by fabric contaminants
    - Easy to understand and fix
        - Functionally intuitive
        - Major components easily identified
        - Good Manual
    - Spare parts readily available

- Simple parts
    - Commercially available components
    - Inexpensive parts
    - Easy to assemble
- Robust
    - Overdesigned
    - Can accommodate abuse
- Reliable
    - Long parts service life

Appendix D - Revised Technical Requirements

- No individual is required to monitor the system
    - Automatic/Semi-Automatic
        - Automatic on-loading
        - Automatic off-loading
    - Minimal human effort
        - Guides provide motive power
        - Guide self aligns
- The guides are inexpensive in every aspect
    - Simple construction
        - Bolted assembly
        - Functionally obvious
    - Commercial components
        - Standard
        - Heavy duty
- The guides can be retrofit to any air-floatation table
    - Not sensitive to table configurations
        - No table modifications
            - No table top modifications
                - Realignments
                - Grooves/Holes
                - Structural changes
            - No under-table modifications
                - Small space
                - No storage interference
    - Not sensitive to spreader configurations
        - Left and/or right reference edge
        - Any size spread
        - Any type material
        - Accommodated spreading paper
        - No spreader interference
            - Cloth feed
                - Hand
                - Chute
            - End trimming
                - Scissors
                - Knife
            - Power supply
                - Human
                - Electrical
            - Concurrent cutting
    - Not sensitive to manual cutting
        - Scissors
        - Rotary knives
        - Reciprocating knives
    - Not sensitive to automated cutting
        - Synchronized feed

        - Cutter station control
- The guides do not interfere with the spreading operation
    - Not sensitive to spreader configurations
        - Left and/or right reference edge
        - Any size spread
        - Any type material
        - Accommodated spreading paper
        - No spreader interference
            - Cloth feed
                - Hand
                - Chute
            - End trimming
                - Scissors
                - Knife
            - Power supply
                - Human
                - Electrical
            - Concurrent cutting
    - Not sensitive to manual cutting
        - Scissors
        - Rotary knives
        - Reciprocating knives
    - Not sensitive to automated cutting
        - Synchronized feed
        - Cutter station control

- The guides minimize spread distortion
    - No wrinkles
    - No edge distortion
    - No snap/back
    - No spread misalignment

- The guides do not interfere with manual cutting
    - Not sensitive to manual cutting
        - Scissors
        - Rotary knives
        - Reciprocating knives

Appendix E - Final Technical Requirements

Automatic
Bolted assembly
Commercial heavy duty components
No table realignment
No structural changes
No table surface modifications
No storage interference
Left and/or right reference edge
Any spread size
Any fabric type
Accommodated spreading paper
No spreader changes
Concurrent spreading/cutting
No interference with manual cutting
Synchronized feed with CNC cutting
CNC Cutter station control
No wrinkles
No edge distortion
No snap/back
No spread misalignment

Appendix F - AMCIA Input Values

AMCIA Input Values for 24 and 36 Month Payback Analysis			
Worksheet	Heading	Subheading	Value Entered
Company Data Sheet	# of annual work weeks		49
	Interest rate on 3 month T-bill		5.6%
	Current company tax rate		35%
	Fringe benefit as percent of payroll	Direct Labor	23.0%
		Indirect Labor	25.0%
	Average unit sales price of the product using current technology	Year 1	\$3.98
		Year 2	\$4.00
		Year 3	\$4.10
		Year 4	\$4.20
		Year 5	\$4.30
		Year 6	\$4.40
	Estimated to be number of units produced using current technology	Year 1	172449
		Year 2	172449
		Year 3	172449
		Year 4	172449
		Year 5	172449
		Year 6	172449
Company Data Sheet (Optional)	Beta value of your company		0.85
	Beta value of your industry		0.85
Investment, Installation, and Depreciation	Investment required for the project	Year 0	–\$2020
	Original stated asset value of the new equipment		–\$2020
	Estimated retraining expense	2hrs X (\$30/hr$_{trainer}$ + \$6/hr$_{trainee}$)	–\$72
	Estimated installation expense	\$30/hr$_{trainer}$ X 2days X 8hrs/day	Year 0: –\$480
Old Equipment Sale			No Values Inserted
Continued on next page.			

AMCIA Input Values for 24 and 36 Month Payback Analysis (Continued)			
Worksheet	Heading	Subheading	Value Entered
Direct Labor	S.A.M. per unit[1] (Present)	(3people X 7min/person) / 2400 completed units	Present: 8.75×10^{-3}
		(3people X 5min/person) / 2400 completed units	Present: 6.25×10^{-3}
		(3people X 3min/person) / 2400 completed units	Present: 3.75×10^{-3}
		(2people X 7min/person) / 2400 completed units	Present: 5.83×10^{-3}
		(2people X 5min/person) / 2400 completed units	Present: 4.17×10^{-3}
		(2people X 3min/person) / 2400 completed units	Present: 2.50×10^{-3}
	S.A.M. per unit[1] (Projected)	(1person X 7min/person) / 2400 completed units	Projected: 2.92×10^{-3}
		(1person X 5min/person) / 2400 completed units	Projected: 2.08×10^{-3}
		(1person X 3min/person) / 2400 completed units	Projected: 1.25×10^{-3}

Continued on next page.

[1] No allowances were made for personal fatigue and delay (P.F.&D.) in calculating the Standard Allowed Minutes

AMCIA Input Values for 24 and 36 Month Payback Analysis (Continued)			
Worksheet	Heading	Subheading	Value Entered
Direct Labor	Base rate per minute	\$3.00/hr	\$0.0500/min
		\$3.50/hr	\$0.0583/min
		\$4.00/hr	\$0.0667/min
		\$4.50/hr	\$0.0750/min
		\$5.00/hr	\$0.0833/min
		\$5.50/hr	\$0.0917/min
		\$6.00/hr	\$0.1000/min
		\$6.50/hr	\$0.1083/min
		\$7.00/hr	\$0.1167/min
	Efficiency	Present	85%
		Projected	100%
	Excess costs as a % of the earned pay/unit	Present	0%
		Projected	0%
	Discount rate		14%
Indirect Labor			No Values Inserted
Materials			No Values Inserted
Quality Related Costs			No Values Inserted
Inventory			No Values Inserted

Continued on next page.

AMCIA Input Values for 24 and 36 Month Payback Analysis (Continued)			
Worksheet	Heading	Subheading	Value Entered
Maintenance	Year 1 ($159)	Belt Cleaned: 30min/week X 49week/year	Total Time: 1470 min/year + 80 min/year + 40 min/year + 1590 min/year
		Bearings Lub'ed: 2Lubes/year X 40min/lube	Total Cost Calculation: 1590 min/year X 1hr/60min X $6/hour
		Motor Lub'ed: 2Lubes/year X 20min/lube	Total Cost: $159
	Year 2	Year 1 X 110%	$175
	Year 3	Year 2 X 110%	$192
	Year 4	Year 3 X 110%	$212
	Year 5	Year 4 X 110%	$233
	Year 6	Year 5 X 110%	$256
	Discount rate		5.6%
Fabric Utilization			No Values Inserted
Miscellaneous			No Values Inserted
Quality Revenues			No Values Inserted
Response-Time Revenues			No Values Inserted
End of AMCIA Input Data Table			

Appendix G - AMCIA Output Values

AMCIA 24 Month Return On Investment Output				
Label	A	B	C	D
	X-Values	Y-Values	Spreads/Day	Spreads/Year
1	$3.00	5.83	5.13	1256
2	$3.50	5.83	4.40	1077
3	$4.00	5.83	3.84	941
4	$4.50	5.83	3.42	837
5	$5.00	5.83	3.07	753
6	$5.50	5.83	2.79	684
7	$6.00	5.83	2.56	628
8	$6.50	5.83	2.36	579
9	$7.00	5.83	2.20	538
10	$3.00	6.67	4.63	1135
11	$3.50	6.67	3.98	974
12	$4.00	6.67	3.47	851
13	$4.50	6.67	3.09	757
14	$5.00	6.67	2.78	681
15	$5.50	6.67	2.53	619
16	$6.00	6.67	2.31	567
17	$6.50	6.67	2.14	524
18	$7.00	6.67	1.98	486
19	$3.00	7.50	4.23	1036
20	$3.50	7.50	3.63	889
21	$4.00	7.50	3.17	777
22	$4.50	7.50	2.82	691
23	$5.00	7.50	2.54	622
24	$5.50	7.50	2.31	565
25	$6.00	7.50	2.11	518
26	$6.50	7.50	1.95	478
27	$7.00	7.50	1.81	444
28	$3.00	4.17	7.19	1762
29	$3.50	4.17	6.17	1511
30	$4.00	4.17	5.39	1321
31	$4.50	4.17	4.79	1174
32	$5.00	4.17	4.31	1057
33	$5.50	4.17	3.92	960
34	$6.00	4.17	3.60	881
35	$6.50	4.17	3.32	813
36	$7.00	4.17	3.08	755

Continued on next page.

AMCIA 24 Month Return On Investment Output (Continued)				
Label	A X-Values	B Y-Values	C Spreads/Day	D Spreads/Year
37	$3.00	5.00	6.26	1534
38	$3.50	5.00	5.37	1315
39	$4.00	5.00	4.69	1150
40	$4.50	5.00	4.17	1022
41	$5.00	5.00	3.76	921
42	$5.50	5.00	3.41	836
43	$6.00	5.00	3.13	767
44	$6.50	5.00	2.89	708
45	$7.00	5.00	2.68	657
46	$3.00	2.50	12.05	2952
47	$3.50	2.50	10.33	2531
48	$4.00	2.50	9.04	2214
49	$4.50	2.50	8.03	1968
50	$5.00	2.50	7.23	1772
51	$5.50	2.50	6.57	1609
52	$6.00	2.50	6.02	1476
53	$6.50	2.50	5.56	1362
54	$7.00	2.50	5.16	1264
55	$3.00	2.92	9.71	2378
56	$3.50	2.92	8.32	2039
57	$4.00	2.92	7.27	1782
58	$4.50	2.92	6.47	1585
59	$5.00	2.92	5.82	1427
60	$5.50	2.92	5.29	1296
61	$6.00	2.92	4.85	1189
62	$6.50	2.92	4.48	1097
63	$7.00	2.92	4.16	1018
64	$3.00	3.75	8.08	1980
65	$3.50	3.75	6.93	1698
66	$4.00	3.75	6.06	1484
67	$4.50	3.75	5.39	1320
68	$5.00	3.75	4.85	1189
69	$5.50	3.75	4.41	1080
70	$6.00	3.75	4.04	990
71	$6.50	3.75	3.73	914
72	$7.00	3.75	3.46	848
73	$3.00	4.58	6.93	1697
74	$3.50	4.58	5.94	1455

Continued on next page.

AMCIA 24 Month Return On Investment Output (Continued)				
Label	A	B	C	D
	X-Values	Y-Values	Spreads/Day	Spreads/Year
75	$4.00	4.58	5.19	1272
76	$4.50	4.58	4.62	1131
77	$5.00	4.58	4.16	1018
78	$5.50	4.58	3.78	925
79	$6.00	4.58	3.46	848
80	$6.50	4.58	3.20	783
81	$7.00	4.58	2.97	727
82	$3.00	2.08	13.40	3284
83	$3.50	2.08	11.49	2816
84	$4.00	2.08	10.04	2461
85	$4.50	2.08	8.93	2189
86	$5.00	2.08	8.04	1971
87	$5.50	2.08	7.31	1790
88	$6.00	2.08	6.71	1645
89	$6.50	2.08	6.19	1516
90	$7.00	2.08	5.74	1407
91	$3.00	2.92	10.49	2571
92	$3.50	2.92	9.00	2205
93	$4.00	2.92	7.87	1927
94	$4.50	2.92	7.00	1714
95	$5.00	2.92	6.30	1543
96	$5.50	2.92	5.72	1402
97	$6.00	2.92	5.24	1285
98	$6.50	2.92	4.84	1187
99	$7.00	2.92	4.49	1101
100	$3.00	1.25	23.19	5682
101	$3.50	1.25	19.89	4873
102	$4.00	1.25	17.38	4259
103	$4.50	1.25	15.46	3788
104	$5.00	1.25	13.92	3410
105	$5.50	1.25	12.64	3098
106	$6.00	1.25	11.60	2841
107	$6.50	1.25	10.71	2623
108	$7.00	1.25	9.93	2434
End of 24 Month ROI Data				

AMCIA 36 Month Return On Investment Output				
Label	A	B	C	D
	X-Values	Y-Values	Spreads/Day	Spreads/Year
1	$3.00	5.83	3.51	860
2	$3.50	5.83	3.01	738
3	$4.00	5.83	2.63	645
4	$4.50	5.83	2.34	573
5	$5.00	5.83	2.11	516
6	$5.50	5.83	1.91	469
7	$6.00	5.83	1.76	430
8	$6.50	5.83	1.62	397
9	$7.00	5.83	1.50	368
10	$3.00	6.67	3.18	778
11	$3.50	6.67	2.72	667
12	$4.00	6.67	2.38	583
13	$4.50	6.67	2.11	518
14	$5.00	6.67	1.91	467
15	$5.50	6.67	1.73	424
16	$6.00	6.67	1.59	389
17	$6.50	6.67	1.47	359
18	$7.00	6.67	1.36	333
19	$3.00	7.50	2.90	710
20	$3.50	7.50	2.48	608
21	$4.00	7.50	2.17	532
22	$4.50	7.50	1.93	473
23	$5.00	7.50	1.74	426
24	$5.50	7.50	1.58	387
25	$6.00	7.50	1.46	357
26	$6.50	7.50	1.34	328
27	$7.00	7.50	1.24	304
28	$3.00	4.17	4.92	1206
29	$3.50	4.17	4.22	1035
30	$4.00	4.17	3.69	904
31	$4.50	4.17	3.28	804
32	$5.00	4.17	2.96	724
33	$5.50	4.17	2.69	658
34	$6.00	4.17	2.46	603
35	$6.50	4.17	2.27	557
36	$7.00	4.17	2.11	517
37	$3.00	5.00	4.29	1050
38	$3.50	5.00	3.68	901

Continued on next page.

AMCIA 36 Month Return On Investment Output (Continued)				
Label	A	B	C	D
	X-Values	Y-Values	Spreads/Day	Spreads/Year
39	$4.00	5.00	3.21	787
40	$4.50	5.00	2.86	700
41	$5.00	5.00	2.57	630
42	$5.50	5.00	2.34	573
43	$6.00	5.00	2.14	525
44	$6.50	5.00	1.98	485
45	$7.00	5.00	1.84	450
46	$3.00	2.50	8.25	2021
47	$3.50	2.50	7.07	1733
48	$4.00	2.50	6.18	1515
49	$4.50	2.50	5.50	1347
50	$5.00	2.50	4.95	1213
51	$5.50	2.50	4.50	1102
52	$6.00	2.50	4.13	1011
53	$6.50	2.50	3.81	933
54	$7.00	2.50	3.53	866
55	$3.00	2.92	6.64	1628
56	$3.50	2.92	5.70	1397
57	$4.00	2.92	4.98	1220
58	$4.50	2.92	4.43	1085
59	$5.00	2.92	3.99	977
60	$5.50	2.92	3.62	888
61	$6.00	2.92	3.32	814
62	$6.50	2.92	3.07	752
63	$7.00	2.92	2.85	698
64	$3.00	3.75	5.54	1357
65	$3.50	3.75	4.90	1200
66	$4.00	3.75	4.15	1017
67	$4.50	3.75	3.69	904
68	$5.00	3.75	3.32	814
69	$5.50	3.75	3.02	739
70	$6.00	3.75	2.77	678
71	$6.50	3.75	2.56	626
72	$7.00	3.75	2.37	581
73	$3.00	4.58	4.74	1162
74	$3.50	4.58	4.07	996
75	$4.00	4.58	3.56	871
76	$4.50	4.58	3.16	775

Continued on next page.

AMCIA 36 Month Return On Investment Output (Continued)				
Label	A	B	C	D
	X-Values	Y-Values	Spreads/Day	Spreads/Year
77	$5.00	4.58	2.85	698
78	$5.50	4.58	2.59	634
79	$6.00	4.58	2.37	581
80	$6.50	4.58	2.19	537
81	$7.00	4.58	2.03	498
82	$3.00	2.08	9.28	2274
83	$3.50	2.08	7.97	1952
84	$4.00	2.08	6.96	1706
85	$4.50	2.08	6.20	1518
86	$5.00	2.08	5.58	1366
87	$5.50	2.08	5.07	1242
88	$6.00	2.08	4.64	1138
89	$6.50	2.08	4.29	1051
90	$7.00	2.08	3.98	975
91	$3.00	2.92	7.26	1778
92	$3.50	2.92	6.22	1525
93	$4.00	2.92	5.44	1333
94	$4.50	2.92	4.84	1185
95	$5.00	2.92	4.36	1067
96	$5.50	2.92	3.96	969
97	$6.00	2.92	3.63	889
98	$6.50	2.92	3.35	821
99	$7.00	2.92	3.11	762
100	$3.00	1.25	15.88	3890
101	$3.50	1.25	13.62	3337
102	$4.00	1.25	11.90	2915
103	$4.50	1.25	10.58	2593
104	$5.00	1.25	9.53	2335
105	$5.50	1.25	8.66	2121
106	$6.00	1.25	7.94	1945
107	$6.50	1.25	7.33	1796
108	$7.00	1.25	6.80	1666
End of 36 Month ROI Data				